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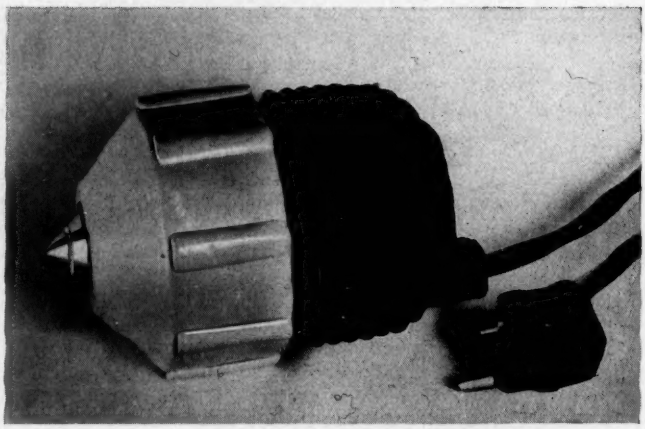

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Brit. J. Ophthal. (1957) **41**, 321.

COMMUNICATIONS

RETINOPATHY OF PREMATURITY (RETROLENTAL FIBROPLASIA) IN CHILDREN IN WHOM THE DISEASE HAS NOT PROGRESSED TO COMPLETE BLINDNESS, AND THE SUBSEQUENT INVESTIGATION OF CASES OF MYOPIA*

BY

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London

THE CLINICAL course of the eye disease in children known as retrolental fibroplasia is now well established as the result of observations from many workers in different countries. The long-term results of the disease in incomplete cases are still uncertain, since the condition is of recent origin. While recording the progress of these incomplete or abortive cases, information was obtained which appeared to give a new aspect to the causation of myopia.

Summary of Findings on Retrolental Fibroplasia

The term retrolental fibroplasia was coined by Terry (1942; 1945), who described the condition as an eye disease syndrome in which vascularized connective tissue developed behind the lens during the first months of life. Terry was the first to associate retrolental fibroplasia with prematurity and, in his series of 117 cases, only eight occurred in full-term infants. King (1950) reported the findings in 238 cases, including Terry's original patients. The incidence of the disease was found to vary inversely with the birth weight. Clinical observers agree that retrolental fibroplasia is almost always bilateral, though it may be much more extensive in one eye than the other.

At the stage of full development of the disease, which is usually between 4 and 6 months after birth, the eyes show a varying degree of microphthalmos, because for some reason they fail to develop normally after the membrane has formed. King noted that an eye with a complete membrane is smaller than its fellow eye with an incomplete membrane. A comparison may be drawn here with rubella cataract, in which condition microphthalmos also occurs, and is noticeable in monocular involvement of the lens, when comparison can be made with the unaffected eye. Gregg (1941) observed microphthalmos in two-thirds of his cases of unilateral cataract, and Swan, Tostevin, Moore, and Black (1943) and Swan (1944) found, on *post mortem* examination of one case of monocular cataract, that the volume of the cataractous eye was only three-quarters that of the normal eye.

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In retrolental fibroplasia, where partial membranes are present, they are frequently triangular in form, with the base of the triangle placed peripherally in the region of the pars plana and ciliary body, and the apex pointing back towards the disc. The membrane in such cases occurs most frequently on the temporal side of the globe, while localized areas of retinal detachment may be present and persist. Retinal and vitreous haemorrhages may also occur.

Clinical Course.—In its acute phase this is characterized ophthalmoscopically by dilatation and tortuosity of the retinal vessels, vitreous hazing, oedema of the retina with transudation of fluid, new vessel formation in the retina, and retinal detachment. Certain authors state that vascular constriction in the retina precedes the vasodilatation, which would agree with the experimental findings in the kitten retina by Ashton and Cook (1953, 1954). Tortuosity of the vessels is generally regarded as the first sign of the disease (Kauffman, 1950; Lamotte and Tyner, 1950). Some observers regard vitreous haze as a fundamental diagnostic feature, but others do not mention it. Tyner (1951) and Fletcher (1953) report hazy ocular media as a common occurrence in premature babies, whether they develop retrolental fibroplasia or not.

In the cicatricial phase, varying clinical manifestations occur, a complete retrolental membrane or a partial one, as previously described. In addition, disc malformations, pallor, and pigmentation of the fundus with attenuation of the retinal vessels, have all been noted. Shallowness of the anterior chamber, posterior synechiae, corneal opacities, cataract, and secondary glaucoma are frequent manifestations in the terminal stages of retrolental fibroplasia.

The microphthalmos which occurs has already been mentioned. When the disease has progressed to blindness, nystagmus of a 'searching' type is present. Photophobia is a common clinical finding in retrolental fibroplasia in the acute phase.

Pathology.—The pathological findings have been divided into three stages by Ashton (1954):

Stage 1 consists in an excessive proliferation of vasoformative tissue in the inner retinal layers. This tissue breaks through the internal limiting membrane, and, at the same time, protein transudates seep through the retina and into the vitreous.

Stage 2 is characterized by an extension of the fibro-vascular tissue into the vitreous, with formation of strands of fibrous tissue. The retina commences to detach.

Stage 3 consists in an extension of the fibrous tissue formation which, by contracture, completes the detachment of the retina. Heath (1950), referring to a retinopathy of premature birth, noted that the anterior loop of uncoapted redundant retina lay in a region of the greatest ocular growth and activity. At this period, the ciliary body and processes are differentiating and the lens becoming flatter and less spherical.

Krause (1946) considered that retrolental fibroplasia is a neuroectodermal disease, the brain as well as the eye being affected. Dickens (1946) found some experimental evidence in support of this view in his work on the metabolism of rat brain slices, which might be irrevocably altered by excessive oxygen.

The effect of oxygen on developing retinal vessels has been investigated and amply documented by Ashton, Ward, and Serpell (1954), and by Ashton and Cook (1954). These experiments on the developing kitten retina led to the conclusion that the vaso-obliterative effect of oxygen was confined to the retinal vessels and that the severity of the vaso-obliteration was most marked in the least mature vessels. In mature blood-vessels, vaso-obliteration could not be produced. The time required to produce vaso-obliteration was found to be 36 hours in the most vulnerable age groups. On transfer to air, the obliterated vessels only partially re-opened, and an abnormally proliferative vascular network developed as a result of oxygen deficiency in the retina. After total obliteration of the blood-vessels had taken place, fresh blood-vessels were formed from the disc in a profuse and disorderly manner, unlike the regular, layered arrangement of blood-vessels in the normal retina. In the early stages, the retinal vaso-constriction was reversible; the concentration of oxygen administered was also of importance. It appears that the obliterative process represents a specific effect of oxygen on growing vessels, which is in direct proportion to the immaturity of the retinal vessels, the duration of exposure to oxygen, and the degree of oxygen concentration.

Although oxygen is the predominant factor in the aetiology of retrolental fibroplasia, there may well be other contributory factors, since a few cases have occurred in the absence of oxygen therapy. Physiologically, an alteration in the oxygen concentration of the baby occurs at birth, owing to the fact that the oxygen saturation of the foetal blood is approximately 50 per cent., and that this rises to about 90 per cent. after birth. This change in oxygen tension acting on immature retinal tissue may account for some of the isolated cases of retrolental fibroplasia which have occurred where no oxygen therapy has been given, and it may, in other cases, give rise to a less obvious retinopathy.

Association of Prematurity with Ocular and Other Defects.—A birth weight of less than 5½ lb. is the standard criterion for prematurity. In 1950, it was estimated that 23 per cent. of babies weighing less than 3 lb. at birth, developed retrolental fibroplasia, and that 7 per cent. of those under 4½ lb. and 5 per cent. of those over 4½ lb. at birth, were affected.

The eye defects in prematurely-born children examined between the ages of 5 and 17 years were investigated by Eames (1946). He compared 155 of these children with 439 children born at full term, with a birth weight of 5½ lb. or over. The prematurely-born showed an increased incidence of low visual acuity at all ages, with less hypermetropia, and more myopia, as compared

with the children born at full term. In addition to the ocular findings, the greatest difference between the full-term group and the prematurely-born was seen in the incidence of feeble-mindedness, which was 3 per cent. more frequent in the premature children, together with an increased tendency to nervous disorders and speech defects. Potter (1954) found a high incidence of mental defect in his series of 151 children suffering from retrolental fibroplasia, 20 per cent. being definitely mentally defective, while a further 26 per cent. were retarded though probably capable of receiving education. In this series of cases, the figures suggested an inverse relationship between birth weight and mental deficiency, the incidence of which, in babies weighing between 2 and 3 lb. at birth, was 23·7 per cent., roughly double that of babies weighing between 4 and 5 lb., in whom the incidence was 12·5 per cent. These figures lend support to the view that other tissues besides the ocular ones, particularly the nervous tissues, are involved in retrolental fibroplasia.

Relationship of the Developing Fundus Oculi of the Premature Infant to Retrolental Fibroplasia.—This has been investigated by Fletcher (1953), who examined 320 premature infants weighing less than 2,500 g. (5½ lb.) at birth. It was found that half of the babies weighing less than 1,500 g. (approx. 3 lb. 5 oz.) showed an immature fundus which remained stationary for several weeks and then differentiated rapidly (in about a fortnight) into a mature fundus. The immature fundus showed vitreous clouding which tended to obscure fundus details. These, when seen, included an oval disc with small bloodvessels, while the mature fundus presented a spherical disc, bloodvessels of adult distribution, and a clear vitreous.

Babies with retrolental fibroplasia tended to show evidence of increased intra-ocular pressure, while babies with retrolental fibroplasia, and small premature babies, were found to have a high and fluctuating myopia on ophthalmoscopic examination.

Summary of the Case Records in Thirty Children with Retinopathy of Prematurity

The scope of this inquiry comprises the findings in thirty children who were examined from the ocular standpoint. A follow-up examination of children who were known to have had retrolental fibroplasia in infancy was planned. The examination was arranged of those children with incomplete retrolental membranes, in whom some degree of vision could be expected. The records of children with retrolental fibroplasia available to the London County Council for the period 1947–1953 were investigated, and it was found that the proportion of incomplete or abortive cases was 25 per cent. of the total. Further, where one of twins was reported blind as a result of retrolental fibroplasia, the eyes of the other twin were examined. The clinical picture in those children who were known to have developed retrolental fibroplasia is a typical one, and includes, in the majority of cases, a myopic error of refraction, which could not be accounted for on a familial basis.

During the examination of certain cases of myopia occurring in children of school age, it became apparent that the clinical picture, which in several cases had been accepted as consistent with the appearances of congenital myopia, resembled that found in the abortive cases of retrolental fibroplasia. Subsequent inquiry revealed that all of these children had been born prematurely. The case reports of these children are appended separately, and, since prematurity is represented in both groups, the findings in the total number of cases have been analysed. Where possible, the subjective findings of the refraction are given in the case reports, but where this proved impossible, the retinoscopy findings under atropine cycloplegia are recorded.

Refractive Error.—The refractive error encountered in 85 per cent. of the cases was a myopia varying from −2·5 to −18 D. Where the two eyes were unequally affected by the retinopathy of prematurity, it was the eye with the better vision which showed the myopia, and where retinoscopy was possible in the more severely affected eye, a hypermetropic or emmetropic refraction was found. The significance of these findings will be discussed later.

The corrected visual acuity did not exceed 6/12, even in those cases with the least fundus changes. Where it has been possible to follow up these cases, the evidence suggests that, in the great majority, the myopia has not progressed. One of the exceptions to this in the present series was Case 19, one of triplets, who showed an increase in myopia of the order of −3 and −4 D. in the right and left eyes respectively over a period of 6 years, while her triplet sister (Case 20) showed virtually no change in the same period.

Nystagmus.—This was present in half the cases with useful vision. In the majority, the movement was fine and somewhat variable in rhythm, and its direction horizontal, vertical, or rotatory; frequently, the different movements were present in the same eye at different times. The two blind twins, Case 8 and Case 11, showed a typical amaurotic nystagmus, rapid, coarse and roving in nature. In one other child, Case 15, the nystagmus was probably inherited.

Eccentric fixation was associated with the nystagmus in five cases.

Microphthalmos.—Of the 28 cases, fourteen showed unilateral microphthalmos. The microphthalmic eye usually possessed little vision and frequently showed a convergent squint.

Strabismus.—Seventeen cases (60 per cent.) in the series showed strabismus. Sixteen of these were convergent squints, and one also showed vertical imbalance due to a secondary over-action of the inferior oblique. The other case showed a latent vertical heterophoria. Usually, the strabismus was secondary to the eye disease which had led to gross visual impairment of the squinting eye.

Ocular Media.—Opacities in the ocular media were frequently encountered.

Three grossly damaged eyes showed corneal opacities, and one case presented lenticular opacities. Vitreous opacities were evident in two-thirds of the cases.

Disc.—Malformations of the optic nervehead were noted in fourteen cases. The appearance in some cases was that of a coloboma of the disc, while in others the disc appeared to be distorted as the result of contracture of scar tissue. Remnants of glial tissue were seen at the nervehead. Distortion of the nervehead was suggested by the tortuous course of the retinal blood-vessels as they emerged from the disc.

Retina and Choroid.—Thinning, atrophy, and depigmentation of the retina were commonly encountered. Large areas of scarring with pigment disturbance were seen in many fundi where the disease process had been moderately severe; in the most minimal cases, a fine pigmentary mottling of the "pepper-and-salt" variety was apparent at the periphery of the fundi. A "bone corpuscle" type of pigmentation was also noted in some of these cases.

The macula in certain cases appeared elevated and slate-grey in colour, whilst in others it looked red and granular. A fine stippling of pigment was evident in many cases.

The retinal vessels sometimes showed an increased tortuosity, and a diminution in the calibre and number of branches was also noted.

Retinal Detachment.—This was evident in fourteen cases. In thirteen of these, the detachment was localized, the area most often involved being in the temporal half of the globe. Frequently the detachment was triangular in shape, with the apex of the triangle pointing towards the disc and the base in the region of the ciliary body. Two cases developed a retinal detachment at the age of 5 years, whilst in another a vitreous haemorrhage developed (which subsequently cleared up) at the same age. A third child, now aged 6, has recently been reported as developing a retinal detachment.

Retinal Folds.—These were apparent in five cases, and in one case retinal folds extended downwards and laterally from the disc in both eyes, the symmetrical, bilateral appearance suggesting a genetically determined lesion.

Significance of Findings

The myopic refractive error occurred in such a high proportion of these cases that, although the series is small, there is ground for suggesting that the association is a real one. The precise nature of the connexion between the two is by no means clear; myopia does not appear to occur in the eyes which are severely affected, and, as has been previously mentioned, where the two eyes are unequally affected, it is the eye with useful vision which shows the myopia. It is possible that the myopia develops through the weakening of the globe by disease, but this hypothesis does not explain the

finding of a hypermetropic refraction in the more severely affected eye. This latter finding may be analogous to the unilateral microphthalmos which may occur in rubella with uniocular lens changes.

The noxious effect of the rubella virus on the developing eye occurs in the first 3 months of pregnancy, and the effect of prematurity on the eye takes place in the neonatal period, yet there appears to be some fundamental resemblance between the two in their effect on ocular development in that both cases may represent an arrest of development. The myopic refractive error may be a manifestation of abnormal growth; a similar hypothesis has been put forward by Steiger (1913) and Vogt (1924) to the effect that the development of high myopia is determined primarily by an overgrowth of the retina, which is the master-tissue, the enlargement of the globe being secondary to the overgrowth. This theory did not take environmental factors into account, however.

Clinically, the findings in these myopes bear resemblances to other clinical types already described in text-books as congenital axial myopia. In most cases, the diagnosis of congenital myopia is not made until the second or third year of life. The commonest clinical picture described in the cases of congenital myopia recorded hitherto is that of "partial albinism", where the interior of the eye is lacking in pigment. It is postulated that, in this condition, the inner eye alone is affected, the remainder of the body being normally pigmented. Brückner and Franceschetti (1932) recorded the findings in 25 cases of myopia characterized by attenuation of the retinal vessels and a dusky, mottled appearance of the macula; the parents of the children in this series were not myopic.

The myopia occurring in these cases is obviously developmental in origin, but the diagnosis is incomplete, since it has not, so far, been found practicable to examine these children and determine what components in the refractive system of the eye are responsible, and in this connexion, further research is obviously indicated. The myopia may be caused by changes in the refracting media or axial length of the eye; either of these factors or a combination of both may be responsible. An increase in the curvature of the cornea may occur, depending on the growth and elasticity of the cornea and sclera and the intra-ocular pressure. Since the opening of the angle of the anterior chamber is a slow process, occurring relatively late in foetal life, this comparatively inadequate drainage system may lead to a stretching of the coats of the eye, and hence to myopia. Where a rise in ocular tension occurs in this way, as in buphthalmos, the refraction is not necessarily myopic, owing to a flattening of the cornea and lens, which compensates for the increase in axial length.

Changes in the structure of the lens may be a causative factor in myopia. From the third to the 8th month of foetal life, the lens is increasing in size and becoming more spherical. The ciliary muscle develops at the fifth month, when the meridional portion of the muscle is well differentiated. By

the sixth month, the circular fibres may be recognized, and accommodation in the premature child is therefore possible and cannot be ruled out as a cause of the fluctuating myopia which has been reported.

A change in the composition of the fluid media may occur in acute stages of retrolental fibroplasia as a result of the transudation of protein exudates through the walls of the dilatated and tortuous retinal vessels. The higher refractive index caused by the increased protein could lead to a myopic refraction, but this state of affairs would be unlikely to persist for any length of time. An increase in the axial length of the eye has long been considered an important factor in the aetiology of myopia. Keeney (1951) states that the length of the foetal eye increases from 14 to 17 mm. during the last 3 months of foetal life; during this period, the eyes of premature children are exposed to a radical change in environment and the coats of the eye, though formed, are thin and very elastic.

The nystagmus, in these cases, is, needless to say, ocular in type. Ocular nystagmus occurs in many conditions where fixation is difficult or impossible, although, in one sense, nystagmus differs only in degree from normal fixation, in which the eye is never absolutely motionless. When a normal eye is looking steadily at a given object, constant muscular activity occurs to ensure that the actions of the various muscles are balanced against one another, and this constant activity leads to fine rotatory movements of the eye. Nystagmus may thus be looked upon as an adaptation to attempt to achieve fixation, in spite of obstacles, by exaggerated effort. The nystagmus, in these cases, can be regarded as the result of impaired function of the macula, the abnormal structure of which can be seen ophthalmoscopically in many of these children. The eccentric fixation may be of similar origin, but may arise as the result of displacement of the macula by traction of scar tissue in the periphery of the retina.

All the squints which were observed occurred in eyes grossly affected by disease. Binocular vision can only be developed when the vision of the two eyes is equal. Where the vision of the two eyes is unequal, development of the normal binocular reflexes is hampered. If the function of an eye is severely impaired in early childhood, accommodation leads to excessive convergence, which is not controlled by the binocular reflexes, and a convergent squint ensues. This would appear to have been the sequence of events in these children.

The vitreous opacities can be readily explained as a sequel to the angioblastic process in the vitreous and the associated transudation of protein. Fletcher (1953) found that the vitreous in premature babies is cloudy for several weeks and clears subsequently, the ultimate progress of the eye depending on whether it has developed retrolental fibroplasia or not.

The colobomatous appearance of the disc in many of these cases was due to distortion of the blood-vessels and glial tissues through traction by scar

tissue in the fundus. It is possible that the appearance in other cases was that of a true coloboma, which is due to deformities of the primitive epithelial papilla (Mann, 1937).

The fundus appearances are consistent with the end-results of a disturbance of vascular origin. Fine pigmentation of the "pepper-and-salt" variety was noted, and the retina was often found to be albinotic, thin, and atrophic. With reference to albinism, Mann (1937) states that the differentiation of the macula, which is not completed until 6 months after birth, is related in some way to normal pigmentation and to the formation of a clear image on the retina. Keeney (1951) says that the stimulation of light appears to be necessary to the completion of retinal development. The lack of pigment in these cases may be due to the retinal atrophy which occurs as a sequel to the acute phase of retrolental fibroplasia; it is also possible that the pathological process may interfere with the development of choroidal pigment which occurs in the sixth month of intra-uterine life. The differentiation of the macula may be hindered through environmental disturbances at the crucial period of development. The frequent localization of retinal detachments in the temporal half of the globe is thought to have some connexion with the impaired function of the macula. Michaelson (1954) investigated, histologically, the vascular system in the eyes of man and animals, and found in the developing human retina that the upper temporal vessels are nearly always longer than the lower. In the same fundus, both temporal vessels are always longer than the nasal vessels when measured from the edge of the disc. The difference in length is not due to a difference in the rates of growth. It could be due to different starting times or to a difference in the area of retina to be traversed. The area of retina temporal to the disc is 50 per cent. greater than that of the nasal portion and contains more ganglion cells. Michaelson suggests that new vessel formation is a function of retinal activity, which is probably greater on the temporal side. Another hypothesis is that the greater distance to be traversed by the temporal vessels may delay maturation of the vascular pattern of the temporal side of the retina. This immaturity could produce a susceptibility to anoxia. In all these considerations, the macula, being on the temporal side of the disc, is involved.

The retinal detachments have all occurred in the first 8 years of life, during which period a great increase in axial length occurs. This increase averages 8 mm. in normal eyes. It is possible that the detachments are associated with a stress between the enlarging sclera on the one hand and the scarred retina on the other.

Summary

In view of the finding that retinopathy of prematurity is associated with myopia, and that in certain cases it has been possible to correlate myopia with prematurity, it is suggested that the association between the two is a real one, and that prematurity is one of the factors in the causation of myopia. The new finding, in itself, provokes further inquiry as to the nature of the

myopia and the mechanism of its production. More use might be made of the term, retinopathy of prematurity, in view of the wide variety of clinical findings covered by this title.

I should like to record my indebtedness to Sir Stewart Duke-Elder for his kindness in perusing this paper.

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APPENDIX

Case Reports

(A) Cases in which the diagnosis of retrolental fibroplasia had already been made.

Case 1, male, born 5.6.51, at 7 months, birth weight 3 lb., in oxygen tent 5 weeks.

Right eye showed a good red reflex and fixed eccentrically. A fine nystagmus was present. Iris blue. The fundus oculi showed distortion of the disc and fine pigmentary stippling in the macular region. Retinoscopy under atropine revealed a myopia of −3 dioptres.

Left eye convergent and microphthalmic, anterior chamber shallow, iris atrophic and discoloured. The fundus showed an extensive retinal detachment in the inferior half of the globe. No retinoscopy was possible.

Case 2, male, born 14.3.49, 10 weeks premature, birth weight 2 lb., in oxygen tent 6 weeks, very frail physique, one of twins, the remaining twin having died shortly after birth.

Both eyes showed a fine nystagmus.

Right eye smaller than left, anterior chamber shallow. Iris hazel brown. The lens was clear, but the vitreous showed numerous fine opacities. A detached fold of retina ran downwards and nasally from the disc, occupying the lower nasal quadrant of the globe. The retina elsewhere showed patchy pigmentation near the equator. Visual acuity—hand movements. Retinoscopy showed refraction −2·5 D sph., −3 D cyl., axis 180°. Correction of myopic astigmatism did not improve acuity.

APPENDIX TABLE

PARTICULARS OF THIRTY CASES

Case No.	Sex	Date of Birth	Period of Gestation (mths)	Birth Weight lb oz	Time in Oxygen Tent (wks)	Refraction Right D sph.	Right D cyl.	Right axis	Left D sph.	Left D cyl.	Left axis	Visual Acuity Right	Visual Acuity Left
1	M	5.6.51	7	3 0	5	−3						not ascertainable	
2	M	14.3.49	6½	2 0	6	−2·5	−3	180°	−1·5	−2	90°	HM	3/60
3	F	8.9.48	7	2 0	6	−2			emmetropic			not ascertainable	
4	M	23.2.50	7	3 6	not known	—	—	—	−11	−2·5	180°	No PL	6/24
5	M	16.12.49	6	3 0	6	−18	−1·5	15°	+6	—	—	6/36	No PL
6	M	15.4.49	7	3 9	2	+4						CF	PL
7	F	26.6.51	7½	3 12	3	−6·5	−0·5	180°	−6·5	−1·5	180°	not ascertainable	
8	M			3 1	5							PL	PL
9	M	19.6.50	6½	3 5	6	−2	+3	90°	−1·5	+4	180°	6/60–6/36	6/60–6/36
10	F	24.10.51	duration uncertain	3 3	4	+1·5			+1			not ascertainable	
11	M			2 11	4							not ascertainable	
12	F	16.8.46	6	2 2	12	—	—	—	−9	−2	155°	No PL	6/18–1
13	F	12.8.46	6	2 0	not known	—	—	—	−1	−1	90°	No PL	4·60
14	M	16.3.50	6	2 4	8	—	—	—	−7			No PL	6/36
15	F	16.4.47	6½	2 8	several	—	+2·75	45°	—	+2·75	120°	6/24 pt	6/24·
16	M	24.7.48	7	2 8	3	−4	−0·75	15°	−0·75	−0·75	180°	3/60	3/60
17	M	25.5.50	7	2 8	8	−15	−2	90°	+2	—	—	6/36	No PL
18	F	29.4.47	8	3 12	4	−7	−0·5	90°	−7	−0·5	80°	6/12	6/12
19	F	3.4.42	7½	2 10	not known	1949: −4	−1	180°	−9	−1	180°	6/18	6/18
						1955: −7	−1	180°	−13	−1	180°	6/18	6/18
20	F			2 12	not known	1950: −10	−1·5	170°	−12	−2	120°	6/18	6/18
						1955: −11			−13			6/18	6/18
21	M	2.1.47	7	4 8	9	—	—	—	−10	−1·5	30°	CF (6 in.)	6·18
22	F	3.8.51	7	2 15	4	−9	−0·5	180°	−5	−4·5	180°	not ascertainable	
						−10	−0·5	180°	−6·5	−2·5	170°	not ascertainable	
23	F	4.6.48	7	2 6	not known	−9	−2	55°	—	—	—	6/36	? PL
24	F	5.2.46	6½	2 4	8	−5	−1	15°	—	—	—	6/12	No PL
25	F	22.10.47	6½	2 8	9	−10	—	—	−8	−3	150°	6/12	3/60
26	M	16.2.51	6	2 11	12	emmetropic			−3·5	—	—	not ascertainable	
27	F	1.11.49	6½	2 12	several	—	−3·5	180°	−4	−3·5	180°	6/36	6/36
28	M	16.11.46	7½	3 0	nil	−16	—	—	−11	—	—	6/12 (6/9 pt)	4/60
29	F	20.5.48	7	3 2	1	—	—	—	−5·5	−1·5	180°	PL	6/36
30	M	17.3.46	6	2 0	12	−4·5	−1·5	105°	—	—	—	3/60	PL

CF=Counting fingers; HM=Hand movements; PL=Perception of light.

Left eye showed eccentric fixation. The anterior chamber and lens were normal. The vitreous showed fine opacities. The retina showed a fold running downwards and nasally from the disc (which was drawn out and distorted) in the 8 o'clock meridian. Both upper and lower margins of the fold were sharply defined, whilst some pigmentation at the periphery of the retina elsewhere was visible. Visual acuity 3/60. Retinoscopy showed refraction −1·5 D sph., −2 D cyl., axis 90°. No improvement was possible with lenses.

Case 3, female, born 8.9.48, 8 weeks premature, birth weight 2 lb., in oxygen tent 6 weeks.

Both eyes showed a fine rotatory nystagmus, and eccentric fixation. Irides blue. The fundus appearances were similar in the two eyes, both discs showing deep excavations resembling congenital colobomata. Retinal folds ran obliquely downwards and temporally from both discs. Subjective estimation of visual acuity was not possible, but retinoscopy showed a myopia of −2 dioptres in the right eye, which was about 20° convergent, and an emmetropic refraction in the left eye.

Case 4, male, born 23.2.50, 8 weeks premature, birth weight 3 lb. 6 oz.

Right eye blind with no perception of light. Eye small, cornea diffusely hazy, anterior chamber obliterated. No red reflex present.

Left eye showed a fine nystagmus. Iris blue. Fine opacities were present in the vitreous, but a clear fundus view was obtained. A crescent, about one-third of a disc diameter in width, was present at the disc, with a generalized lack of pigment throughout the fundus and a very fine pigment stippling. Visual acuity, with −11 D sph., −2·5 D cyl., axis 180°, 6/24 ptly.

Case 5, male, born 16.12.49, 3 months premature, birth weight 3 lb., in oxygen tent 6 weeks.

Right eye highly myopic, anterior segment normal. Iris grey-blue. The posterior segment showed strands of vitreous opacities. The disc appeared rather pale in colour, and had a distorted appearance suggestive of a coloboma. The retinal vessels were tortuous. The fundus as a whole appeared lacking in pigment, and at the same time the periphery showed a fine pigmentary stippling. The macula showed a fine stippling of pigment, but the area surrounding it was unpigmented. Visual acuity, with −18 D sph., −1·5 D cyl., axis 15°, 6/36.

Left eye convergent and microphthalmic, anterior chamber shallow, lens clear. Numerous vitreous opacities were present and the retina showed a detachment in the lower temporal quadrant. There was no perception of light, although retinoscopy was possible and showed a hypermetropia of +6 dioptres.

Case 6, male, born 15.4.49, at 7 months, birth weight 3 lb. 9 oz., in oxygen tent 2 weeks. The baby's eyes were noticed to "roll" a good deal, and he was taken to Moorfields at the age of 3 months.

Both eyes showed a fine nystagmus with, in addition, some coarse "searching" movements. Irides brown.

Right eye showed an anterior chamber of normal depth. The lens was clear. A detached area of retina was visible in the nasal quadrant, and this projected into the retina and prevented a view of the disc. In the lower part of the retina, large whitish patches of choroidoretinal atrophy were present. Retinoscopy showed a moderate hypermetropia of +4 dioptres. Vision was counting fingers only and could not be improved.

Left eye smaller than the right, anterior segment normal. Numerous vitreous opacities were present and a retinal detachment occupied the lower half of the globe, extending horizontally from 3 to 9 o'clock. Large patches of scar tissue could be made out in the upper half of the fundus resembling those seen in the right eye. Vision was perception of light only, and retinoscopy was impossible.

Case 7, female, born 28.6.51, one of twins, 6 weeks premature, birth weight 3 lb. 12 oz., in oxygen tent 3 weeks. Parents not myopic.

Both eyes, media clear, fundi normal, apart from a little stippling at the macular regions. Irides brown. Retinoscopy showed a myopia of about −6 dioptres. Subjective estimation of visual acuity not possible.

Right eye refraction −6·5 D sph., −0·5 D cyl., axis 180°.

Left eye refraction −6·5 D sph., −1·5 D cyl. axis 180°.

Case 8, male, twin brother of Case 7, birth weight 3 lb. 1 oz., in oxygen tent 5 weeks.

Both eyes showed coarse nystagmus and were divergent about 20°. Visual acuity perception of light only. Ocular tension increased, anterior chambers shallow. Irides grey. Both lenses clear, revealing an obvious retrolental membrane in both eyes, though some red reflex was visible above in the left eye.

Case 9, male, born 19.6.50, one of twins, the other twin being stillborn, at 6½ months, birth weight 3 lb. 5 oz., in oxygen tent 6 weeks. Parents not myopic. The child held his head turned to the left, and when looking at objects, focused eccentrically.

Both eyes showed moderate lateral nystagmus, ocular tension normal. Irides blue.

The visual acuity was impossible to assess subjectively but appeared to correspond to about 6/60 or 6/36, small familiar objects being readily identified. Retinoscopy showed a mixed astigmatism.

Right eye convergent, the pupil reacting to light. A large strand of opacity was present in the vitreous while glial tissue blurred the outline of the disc, the vessels at the nervehead being distorted. Refraction: −2 D sph., +3 Dcyl., axis 90°.

Left eye showed a strand of vitreous opacity and distortion of the disc, the outline of which was clear. Below the disc was a patch of pigment. Some stippling of pigment was present at the left macular region. Refraction: −1·5 D sph., +4 D cyl., axis 180°.

Case 10, female, born 24.10.51, one of twins, birth weight 3 lb. 3 oz., period of prematurity not stated, in oxygen tent 4 weeks. Father myopic.

Both eyes showed a fine nystagmus. Irides blue. Retinoscopy showed a normal, slightly hypermetropic refraction.

Right eye convergent, and rather smaller than the left. The lens was clear, but the vitreous showed numerous discrete opacities. The fundus showed a grey elevated patch of retrolental tissue in the lower nasal quadrant, and elsewhere the retina appeared thin and lacking in pigment. A wide-spread shallow detachment occurred in October, 1956. Refraction: +1·5 D sph.

Left eye anterior chamber and lens normal. Vitreous opacities were present, whilst a retinal fold ran downwards and outwards from the disc. The retina appeared thin, atrophic, and lacking in pigment. Refraction: +1 D sph.

Case 11, male, twin brother of Case 10, birth weight 2 lb. 11 oz., generally retarded and obviously totally blind.

Right eye cornea and lens clear, but dense retrolental membrane present.

Left eye small, with corneal opacities, anterior chamber obliterated.

No red reflex was obtainable in either eye, while the ocular tension, as estimated by finger pressure, was increased in the left eye.

Case 12, female, born 16.8.46, at 6 months, one of twins (the other, being more severely affected, was in a Sunshine Home and was not examined on that account), birth weight 2 lb. 2 oz. (twin sister's birth weight 2 lb.), in oxygen tent 12 weeks. Parents not myopic.

Both eyes. Irides blue.

Right eye small and convergent, anterior segment appeared normal. Vitreous showed numerous opacities, and the retina was extensively detached, especially on the temporal side. No retinoscopy was possible. No perception of light.

Left eye, anterior segment normal, but vitreous showed multiple fine opacities. The disc showed some distortion, with a patch of pigmentation at its temporal side. The vessels appeared very tortuous at the periphery, where there were soft creamy patches, their diameter being about three times the width of the vessels. These patches were also present in the central area but less numerous there, while the macula itself appeared greyish and raised. Retina markedly thin and lacking in pigment, choroidal vessels clearly visible. Visual acuity, with −9 D sph., −2 D cyl., axis 155°, 6/18 −1.

Case 13, female, born 12.8.46, 3 months prematurely, birth weight 2 lb., length of time in oxygen tent not known.

Right eye small, showed no perception of light, deep anterior chamber. Iris muddy-grey and adherent at pupil margin to the remains of the lens, needling having been carried out on that eye in infancy.

Left eye, anterior chamber rather shallow. Iris blue-grey. Some adhesions between iris and lens at 4 to 5 o'clock, with a finger of iris tissue running from the anterior surface of the iris to the lens. The lens showed some fine opacities, and the vitreous also showed opacities. Patches of pigmentation and atrophy were seen scattered over the periphery. Visual acuity unaided was 4/60. Retinoscopy showed a low degree of myopia and astigmatism, which, when corrected, did not improve the acuity. Refraction −1 D sph., − D cyl., axis 90°.

Case 14, male, born 16.3.50, 3 months premature, one of twins (the other twin having died shortly after birth), birth weight 2 lb. 4 oz., in oxygen tent 8 weeks. General physique poor.

Both eyes showed fine nystagmus. Irides blue.

Right eye small and showed secondary divergence. Cornea clear, pupil small, anterior chamber shallow, lens clear, dense retrolental membrane and no red reflex. No perception of light.

Left eye, anterior segment normal. A good view of the fundus was possible. The disc was slightly pale, and the fundus in general appeared pale and depigmented. Correction of the myopia of −7 dioptres, gave a visual acuity of 6/36.

Case 15, female, born 16.4.47, gestation 26 weeks, birth weight 2½ lb., in oxygen tent for several weeks, exact duration unknown. General physique rather small for her age. Father short-sighted.

Both eyes showed a moderately fast nystagmus, and the appearances were symmetrical. Irides blue. The pupils and media were clear. Both discs were inverse, the vessels entering on the temporal side and becoming rather tortuous and attenuated towards the periphery of the retina. Both retinae appeared markedly thin, with very little pigment, while on the nasal sides of both discs there was some atrophy of the choroid, with baring of the sclera. Both maculae were granular and finely stippled with pigment, and some rather coarser pigmentary stippling was present at the periphery of the retina. Visual acuity in the right eye, with +2·75 D cyl., axis 45°, 6/24 ptly, and in the left eye, with +2·75 D cyl., axis 120°, 6/24.

Case 16, male, born 24.7.48, 8 weeks premature, birth weight 2½ lb., in oxygen tent 3 weeks. Father has nystagmus but neither parent myopic.

Both eyes showed a rapid lateral nystagmus.

Right eye about 10° convergent, media clear apart from a few very fine vitreous opacities; disc pale, vessels rather narrow, macula slate-grey and slightly elevated. Visual acuity, with −4 D sph., −0·75 D cyl., axis 15°, 3/60.

Left eye presented the same appearance as the right. Visual acuity, with −0·75 D sph., −0·75 D cyl., axis 180°, 3/60.

The nystagmus in this child was much faster and more rhythmical than in the other cases in this series, and was probably hereditary in nature (see above). The appearance of the maculae corresponded to that of the other cases of retrolental fibroplasia.

(*B*) *Cases in which the possibility of retinopathy of prematurity was considered after examination.* The ocular findings are given first, and the birth history subsequently, to emphasize this fact.

Case 17, male, born 25.5.50, was referred as a case of "congenital myopia". Neither parent myopic. There was a moderate amount of general retardation.

Both eyes showed a fine rotatory nystagmus; subjective refraction was impossible but visual acuity was estimated at 6/36.

Right eye, anterior chamber normal, no synechiae. Iris blue. The lens was clear, whilst the vitreous showed a fine strand of opacity and numerous fine dust-like opacities. A large crescent surrounded the right disc, the retinal vessels appeared normal, but the macula showed fine stippling. Towards the periphery of the fundus were coarser patches of pigmentation of the pepper-and-salt type. Retinoscopy showed a high degree of myopia. Refraction −15 D sph., −2 D cyl., axis 90°.

Left eye convergent and small and the ocular tension raised. Cornea clear, anterior chamber shallow, and iris greyish. The pupil did not react to light. The lens was clear. Fine dust-like opacities were present in the vitreous, together with a localized retrolental membrane in the lower temporal quadrant from 3 to 6 o'clock, appearing as a triangular fold stretching up to the disc.

The latter was grey in colour and showed distortion of the vessels. Where the retinal vessels were visible, they appeared tortuous. The periphery of the retina showed large patches of pigmentary disturbance, discrete, pale, rather refractile areas, with pigment tending to deposit at the margin. Refraction +2 D sph.

This child was born at 28 weeks, weight 2lb. 7½oz., in oxygen tent 8 weeks.

Case 18, female, born 29.4.47, was referred as a case of myopia. Neither parent myopic; no family history of myopia. The child was frail and delicate and had had an operation for cleft palate.

Right eye, visual acuity, with −7 D sph., −0·5 D cyl., axis 90°, 6/12.
Left eye, visual acuity, with −7 D sph., −0·5 D cyl., axis 80°, 6/12.
Both eyes, media clear. Irides blue. The discs showed commencing crescent formation; the vessels were normal. The retina appeared greyish in patches, and at the periphery showed some fine stippling and some small patches of pigment. The fundus appearances in this case appeared to represent the most minimal stage of retinopathy of prematurity.

This child was one month premature, birth weight 3 lb. 12 oz., in oxygen tent one month.

Case 19, female, born 3.4.42, was one of triplets, of which two girls survived, and a boy died 8 hours after birth. The eye condition was originally diagnosed as myopia.

In 1949 the refraction in the right eye was −4 D sph., −1 D cyl., axis 180°; and in the left −9 D sph., −1 D cyl., axis 180°. Visual acuity 6/18 in both eyes.
When examined in December, 1955, visual acuity in the right eye was 6/18, with −7 D sph., −1 D cyl., axis 180°, and in the left eye 6/18, with −13 D sph., −1 D cyl., axis 180°. The anterior segments of both eyes were normal, and the media clear. The outline of the right disc was obscured by glial tissue, and at both discs the vessels were distorted. The maculae appeared granular, the periphery showed patchy pigmentation, and the fundi were lacking in pigment.

This child was 6 weeks premature, birth weight 2 lb. 10 oz., in oxygen tent for an uncertain period.

Case 20, triplet sister of Case 19, birth weight 2 lb. 12 oz., also in oxygen tent for an uncertain period.

In 1950 the refraction in the right eye was −10 D sph., −1·5 D cyl., axis 170°; and in the left −12 D sph., −2 D cyl., axis 120°.
In December 1955: visual acuity in the right eye, with −11 D sph., 6/18 (6/12 ptly); in the left eye, with −13 D sph., 6/18.
Both eyes anterior segments normal, fine vitreous opacities. There were crescents at both discs, with some tortuosity of the vessels at the nerve head. Both maculae appeared spongy and granular and the foveae appeared ill-developed, while at the periphery the retina showed fine granular pigmentation.

Cases 19 and 20 had been examined on several occasions before it became apparent that some of these findings corresponded to those seen in retrolental fibroplasia. There was no myopia in either parent, but inquiry revealed the significant factors in their early history. Both twins had blue eyes.

Case 21, male, born 2.1.47, was ascertained as suffering from 'high myopia'. No family history of myopia.

Right eye showed a convergent squint and was rather smaller than the left. Visual acuity counting fingers at 6 inches, no retinoscopy was possible, but examination of the fundus showed fine vitreous opacities. The outline of the disc was blurred, probably partly because of the opacities in the media, the vessels were attenuated, and there were patches of choroidoretinal pigmentary disturbance, larger than the optic disc.
Left eye showed some fine nystagmoid movements. Visual acuity, with −10 D sph., −1·5 D cyl., axis 30°, 6/18. Stringy opacities were present in the vitreous, and the vessels at the disc were distorted. The retina showed an ill-defined, elevated grey patch in the periphery of the temporal quadrant, at 3 o'clock.

This child was 8 weeks premature, birth weight 4½ lb., in oxygen tent 8 weeks.

Case 22, female, born 3.8.51. Parents not short-sighted.

Both eyes showed a high degree of myopia.

In July, 1954, the refractions were: right eye −9 D sph., − 0·5 D cyl., axis 180°; left eye −5 D sph., −4·5 D cyl., axis 180°.

In February, 1955, the myopia had increased to: right eye −10 D sph., −0·5 D cyl., axis 180°; left eye −6·5 D sph., −2·5 D cyl., axis 170°.

Subjective estimation of the visual acuity was not possible. Irides blue. The media were clear, the discs appeared large and slightly pale. Both maculae appeared granular but marked depigmentation of the retinae was evident.

This child was born at 28 weeks, birth weight 2 lb. 15 oz., in oxygen tent 4 weeks.

Case 23, female, born 4.6.48, was thin, rather restless and excitable, but of average intelligence.

Right eye was highly myopic, visual acuity with −9 D sph., −2 D cyl., axis 55°, 6/36. Anterior segment normal, and lens clear. Iris brown. The retina showed some thinning and some fine vitreous opacities were present.

Left eye convergent, smaller than the other, with no fixation; it was doubtful if there was perception of light in that eye. On examination, the anterior segment was normal, the lens clear. The fundi showed scattered areas of pigmentary disturbance including a large patch the size of the disc at the posterior pole. A localized detachment of the retina was present in the lower and outer quadrant, with a fold of retina stretching up towards the disc.

This child was 8 weeks premature, birth weight 2 lb. 6 oz., in oxygen tent for an unknown period.

Case 24, female, born 5.2.46, was rather small and undersized for her age. Neither parent myopic.

Right eye, visual acuity, with −5 D sph., −1 D cyl., axis 15°, 6/12. Anterior segment normal, lens clear. Iris brown. The vitreous was clear, and the disc normal in appearance. Some pigmentation was present at the right macula and fine pigmentation was present at the periphery.

Left eye, small and convergent, lens clear, but a dense retrolental membrane was present. No perception of light.

This child was born at 26 weeks, birth weight 2 lb. 4 oz., in oxygen tent 8 weeks.

Case 25, female, born 22.10.47, was admitted to a school for the partially sighted as a case of myopia. In the course of routine examination, it became apparent that her eyes showed similar clinical features to the cases previously examined.

Both eyes. Irides blue.

Right eye externally normal, ocular movements full; the eye deviated upwards under cover. The vitreous showed fine opacities. The disc appeared large and slightly pale, as is encountered in myopia; the vessels were kinked at the disc before spreading out into the retina, where they showed some tortuosity at the periphery. Fine pigmentary stippling was present at the macula, which appeared rather more spongy and vascular than normal. A patch of retinal atrophy about the size of the disc was present in the periphery at 9 o'clock, and the fundus was lacking in pigment. Visual acuity, with −10 D sph., 6/12.

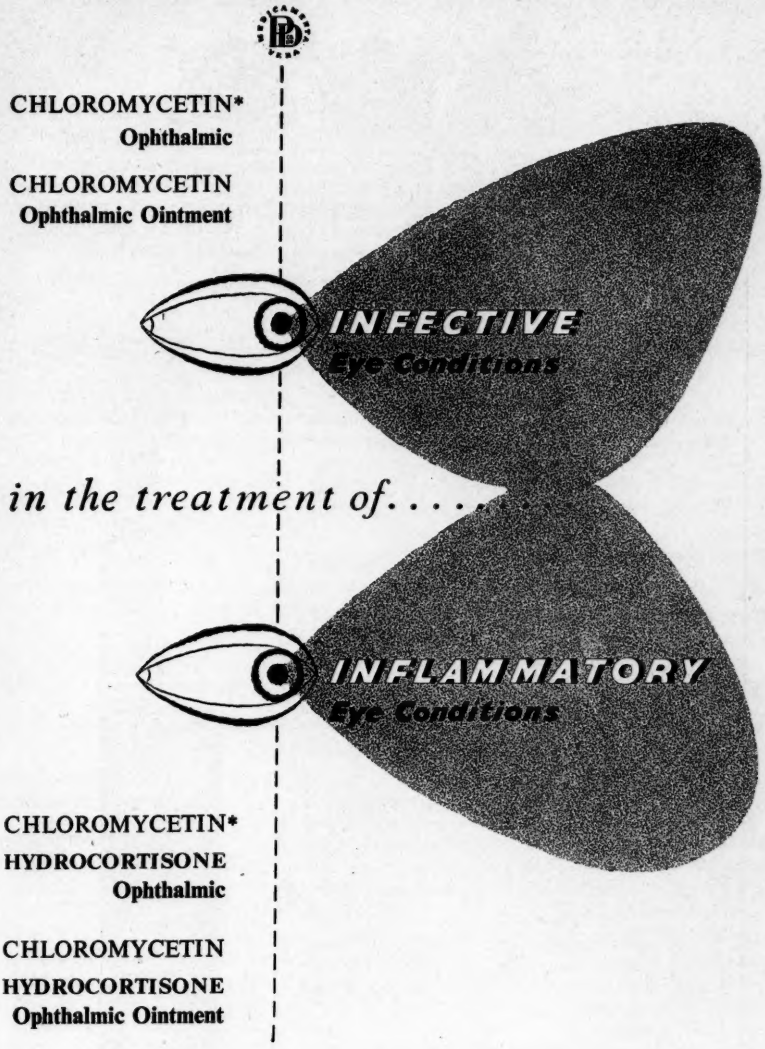
Left eye externally normal but fixation poor. Numerous opacities in the anterior vitreous partly obscured fundus details. The disc was paler than that of the other eye, and the lower margin was sharply demarcated with a deep colobomatous appearance; the fundus showed a general lack of pigment, and several large patches of choroidoretinal atrophy. Visual acuity, with −8 D. sph., −3 D cyl., axis 150°, 3/60.

This child was 10 weeks premature, birth weight 2½ lb., in oxygen tent 9 weeks.

Case 26, male, born 16.2.51, was brought by his mother on account of a squint in his right eye, which had been present from birth. Neither parent myopic.

Both eyes. Irides blue.

Right eye showed a marked convergent squint, with some weakness of the right superior rectus, and over-action of the right inferior oblique. The vision was difficult to assess, but in the right eye it was obviously extremely poor, fixation being lost. Ophthalmoscopic examination showed opacities in the vitreous and a localized detachment of the retina in the upper nasal quadrant. Refraction emmetropic.



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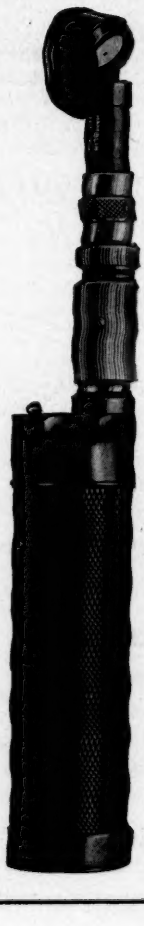

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Left eye relatively normal but showed some lack of pigment and thinning. Refraction −3·5 D myopic.

This child was born at 6 months, birth weight 2 lb. 11 oz., in oxygen tent for 3 months.

Case 27, female, born 1.11.49, was examined at a school for the partially sighted at the age of 6 years. No family history of defective vision.

Both eyes showed nystagmus and eccentric fixation, and the left eye showed a slight convergence. The media were clear. Both optic nerve heads were distorted and the retinae were depigmented and thin. Both maculae showed fine pigmentary stippling.

Right eye, visual acuity, with −3·5 D cyl., axis 180°, 6/36.

Left eye, visual acuity, with −4 D sph., −3·5 D cyl., axis 180°, 6/36.

This child was 10 weeks premature, birth weight 2 lb. 12 oz., in oxygen tent several weeks.

Case 28, male, born 16.11.46, was examined at a school for the partially sighted at age of 7 years. No family history of myopia.

Both eyes, anterior segments of globes appeared normal. Irides blue.

Right eye, media clear, disc distorted and one or two spots of pigmentation were evident at the periphery together with degenerative changes and patches of mottling. Visual acuity with −16 D sph., 6/12 (6/9 ptly).

Left eye showed a convergent squint of about 25°. The vitreous showed numerous opacities, and the disc was distorted. The retina showed marked thinning with fine pigment stippling at the macula. Visual acuity, with −11 D sph., 4/60.

This child was born at 7 months, birth weight 3lb., but was not given oxygen therapy.

Case 29, male, born 20.5.48, was brought for general medical examination at the age of 7 as a case of spastic diplegia and was noted to have an eye defect. Neither parent myopic.

Both eyes showed nystagmus, and fixation in the right eye was poor. Irides blue.

Right eye, visual acuity perception of light only; a retrolental mass of fibrous tissue was seen in the lower temporal quadrant.

Left eye, visual acuity less than 6/60 unaided, but 6/36 with −5·5 D sph., −1·5 D cyl., axis 180°. The vitreous showed numerous opacities and the retina showed thinning.

A diagnosis of retrolental fibroplasia was made. This child, one of twins, was 8 weeks premature, birth weight 3 lb. 2 oz., in oxygen tent 1 week.

Case 30, female, born 17.3.48, in the U.S.A., was brought for examination to determine her educational needs at the age of 7 years. The mother gave a history that an eye defect was noticed at the age of 8 months, when the eyes were noticed to be crossing. At the age of 2, the left eye was given atropine occlusion, in an endeavour to improve the acuity in the right eye, and spectacles were worn between the ages of 2 and 4. In February, 1953, the child was noticed to be feeling for objects and an ophthalmologist diagnosed a detached retina in the left eye. The mother stated that four operations (two scleral resections and two diathermies) had been performed without success. Mother myopic, and stated that the maternal grandmother and two aunts were also myopic.

Right eye visual acuity 2/60 and N.24 fixing eccentrically. Iris blue. Vitreous showed numerous opacities, disc distorted in appearance, and vessels markedly tortuous. The retina was pale and thin and the periphery of the fundus showed patches of choroidoretinal atrophy. Refraction myopic; visual acuity, with −4·5 D sph., −1·5 D cyl., axis 105°, 3/60.

Left eye visual acuity perception of light only. The eye itself was microphthalmic and slightly congested. Iris grey. A secondary cataract had developed.

This child was 3 months premature, birth weight 2 lb., in oxygen tent 3 months. The diagnosis was considered to be retrolental fibroplasia.

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STUDIES ON THE ANTIGENIC STRUCTURE OF THE EYE USING THE FLUORESCENT ANTIBODY TECHNIQUE*

BY

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THE cause of many cases of uveitis is unknown and it therefore seemed useful to examine a technique, little used in ophthalmic pathology, which might help to solve some problems. This method is the antigen-antibody technique of Coons and Kaplan (1950), who coupled fluorescein *iso*cyanate to an antiserum with which they then treated fresh frozen sections of tissue. The site of the antigen-antibody reaction became visible as a green stain when the sections were examined with ultraviolet light. It is thus really a refined histological staining method. It has been used previously on the eye by Clayton (1954) and Clayton and Feldman (1955) to detect antigens of the embryonic lens, and by Witmer (1955) to study the intra-ocular production of antibody.

Hill and Cruickshank (1953) and Cruickshank and Hill (1953) showed that an antiserum to rat glomeruli could be produced in rabbits, and by using the fluorescent antibody technique they showed that this antiserum reacted not only with the glomeruli, but also with basement membranes elsewhere in the body (spleen, lungs, lacrimal glands, blood-vessels, etc.). These workers did not investigate the reaction of their antiglomerular serum with eye tissues, and therefore the present investigations were made, in order to see whether basement membranes in the eye are similar in nature to those found elsewhere and also whether this technique could be successfully applied to the localization of antigen-antibody reactions in the eye.

Methods

Anti-rat glomerular serum was produced in rabbits. Six white rats were used to supply the kidneys; the glomeruli were separated, using the method of Hill and Cruickshank (1953), and were preserved in merthiolate 1/10,000 and stored at −10° C. The whole glomeruli were injected intraperitoneally into two rabbits, each having six doses at weekly intervals. Blood was removed one week later and the serum coupled with fluorescein *iso*cyanate by the method of Coons and Kaplan (1950). It was found that the staining obtained was not satisfactory using whole serum so the globulin was used. This was prepared by precipitating the serum with an equal volume of 50 per cent. ethanol at −10° C., centrifuging the deposit at −5° C., and dissolving the precipitate in normal saline, so that the original serum was concentrated to about half its original volume. This solution was dialysed in the cold against buffered saline at pH 7·0 to remove ethanol. Non-specific staining was removed by repeated absorption with heterologous acetone-washed and dried muscle and liver powders in the cold. The globulin was stored

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at −10° C. in merthiolate 1/10,000. Normal rabbit serum was prepared in the same way; it was coupled with fluorescein *iso*cyanate, the globulins being precipitated and absorbed with heterologous tissue as before.

Cutting of Sections.—Satisfactory frozen sections of the rat eye could not be cut on an ordinary freezing microtome as they disintegrated before being placed on a slide. The method of Linderstrøm-Lang and Mogensen (1938) was therefore adapted. Coons, Leduc, and Kaplan (1951) describe a "Cryostat" in which the microtome is maintained below freezing; in the present experiment a commercial deep-freeze cabinet ("Coldrator", 3 cu. ft.) was used. This has a freezing compartment measuring 21″×11″ and 20″ deep with a removable lid. A sledge microtome was used, and a piece of Perspex laid across the top of the cabinet acted as a shield. Gloves were worn when using the microtome to prevent it becoming coated with frost. A thermometer bulb fixed to the microtome block showed that a temperature of −10° to −15° C. could be maintained under these conditions during cutting, the optimum being around −10° C.

White rats of about 60 g. were killed with ether and the eyes and kidneys rapidly frozen in liquid air. In cutting sections the knife window described by Coons, Leduc, and Kaplan (1951) was found essential to prevent curling. Sections of the eye 25–30μ were the thinnest that could consistently be produced, those of the kidney being about 6μ. Cutting very thin frozen sections of a complete rat eye proved difficult. If such sections are wanted it is probably better to use only small pieces of tissue. Sections were dried under a fan, fixed with 96 per cent. ethanol at 37° C. for 20 min., and stored at −10° C. They were usually used within a few days. Fixation proved necessary to retain the retinal structure after prolonged immersion in solutions of globulin.

Examination of the Sections.—Alternate sections were treated at the same time with fluorescent normal globulin or with fluorescent anti-rat glomerular globulin (ARGG). They were kept moist in a closed container at 37° C. for 2–3 hrs; surplus globulin was then removed by washing in normal saline for 15 min. in a Coplin jar. The sections were dried under a fan and examined immediately; but, if kept at −10° C., the specific staining was visible for many weeks. As a further check, absorption experiments were carried out. In these experiments, sections were treated with non-fluorescent normal or ARG globulin for 3 hrs at 37° C. before being stained with fluorescent globulin, as before. Confirmation of specificity was obtained when, in those sections absorbed with ARGG before being treated with fluorescent ARGG, the staining was either completely prevented or markedly reduced. Absorption with normal serum did not, however, alter the staining obtained with the fluorescent antiserum.

In examining the sections, light of about 360 mμ was used, provided by a Mazda ME/D 250-watt mercury arc lamp with a glass envelope, a glass collecting lens, surface-aluminized mirror, and an ordinary microscope with glass substage condenser. Filters in the illuminating system were Chance OX1 and a $CuSO_4$ tank; on the eyepiece was a pale yellow UV filter. It was found that some mounting media tended to auto-fluoresce; also, fragments of the lens floated about the section; the sections were therefore examined dry without a cover slip. Photomicrography was carried out using Ilford HP3 or PanF 35-mm. film developed in Microphen. An exposure of 2–4 min. was needed.

Results

Kidney.—Studies of the kidney were made both to confirm the potency of the antiserum and to compare the efficiency of the present technique with that of Hill and Cruickshank. In all sections stained with fluorescent ARGG, a thin tortuous line was visible in the glomeruli; a fainter line was visible around the tubules (Fig. 1).

FIG. 1.—Rat kidney (glomeruli and tubules) stained with fluorescent ARGG after section had been treated with normal rabbit globulin. × 190

The larger blood-vessels showed marked auto-fluorescence which masked the specific staining. The picture was in strong contrast to that seen in the controls, which showed only a diffuse non-specific green and in which the glomeruli appeared darker than their surroundings (Fig. 2, opposite).

Specific staining was almost completely prevented by pre-absorption with non-fluorescent ARGG (Fig. 3, opposite).

Eye.—Specific staining with ARGG occurred in the following structures:

Lens.—When the unstained lens was examined with ultraviolet light, the capsule was only faintly visible, whereas the lens substance showed a marked auto-fluorescence. In sections stained with fluorescent normal rabbit globulin, the whole lens including the capsule was faintly green—a non-specific effect (Fig. 4). When treated with fluorescent ARGG, the capsule alone was heavily stained (Fig. 5). This staining was prevented in other sections (Fig. 6) by treating them with non-fluorescent ARGG before staining with fluorescent ARGG. Specificity of staining was thus confirmed.

Iris and Ciliary Body.—The thickness of the sections prevented a study of fine detail. A definite membrane beneath the ciliary epithelium and within

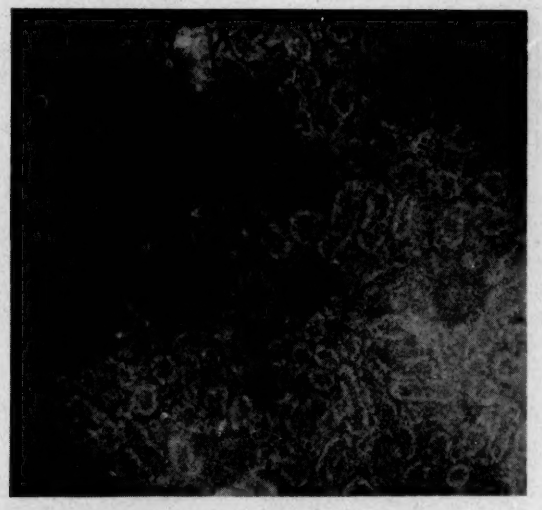


FIG. 2.—Rat kidney (glomeruli and tubules) stained with fluorescent normal rabbit globulin. × 190

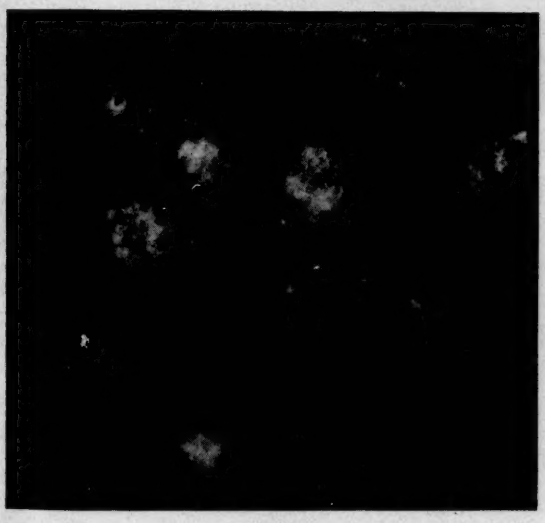
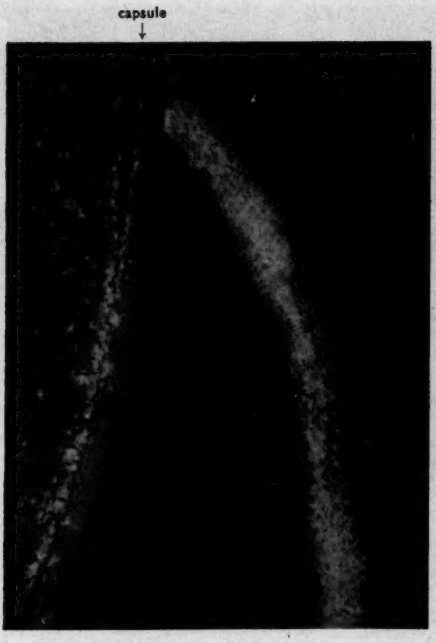


FIG. 3.—Rat kidney (glomeruli and tubules) stained with fluorescent ARGG after section had been treated with ARGG. × 190

the ciliary body was visible. In the iris, a membrane could be seen between the epithelium and stroma, extending into the latter. Staining around the sphincter iridis was much heavier in the ARGG-treated sections than in the controls, suggesting that here too there was a specific antigen. Confirmation was again obtained by absorption (Figs 4, 5, 6, 7, 8, 9, overleaf).

Cornea.—There was so much non-specific staining and auto-fluorescence that any specific staining which may have been present was masked.



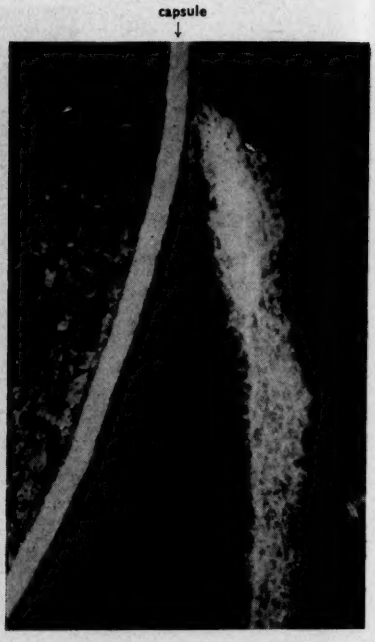


FIG. 4.—Rat eye (lens and iris) stained with fluorescent normal rabbit globulin. ×190

FIG. 5.—Rat eye (lens and iris) stained with fluorescent ARGG. ×190

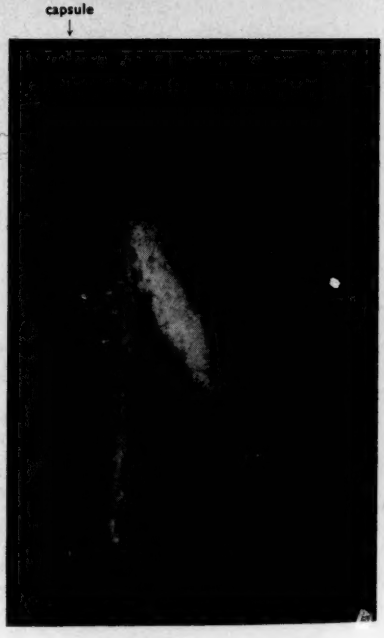


FIG. 6.—Rat eye (lens and iris) stained with fluorescent ARGG after section had been treated with ARGG. ×190

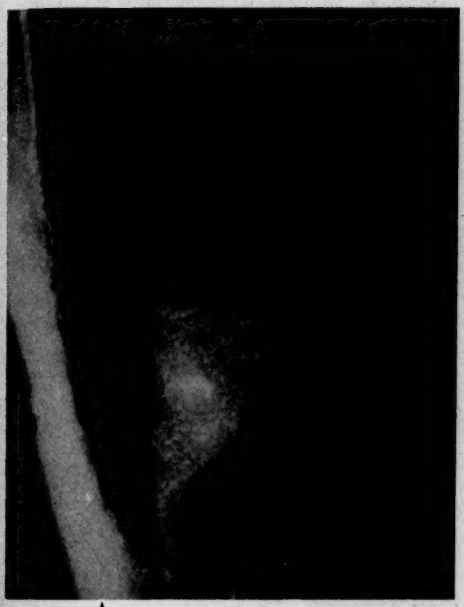


FIG. 7.—Rat eye (ciliary body) stained with fluorescent normal rabbit globulin. ×190

FIG. 8.—Rat eye (ciliary body) stained with fluorescent ARGG. ×190

FIG. 9.—Rat eye (ciliary body) stained with fluorescent ARGG after section had been treated with ARGG. ×190

Conjunctiva.—A faint membrane was visible beneath the epithelium. The smaller blood-vessels also showed definite specific staining.

Posterior Segment.—The sclera showed non-specific staining and auto-fluorescence and again this tended to mask the surrounding structures. The small blood-vessels in both the retina and optic nerve (Figs 10, 11, 12) were specifically stained.

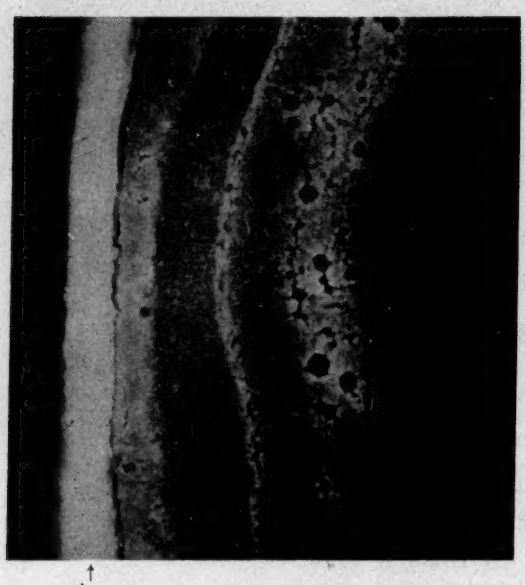


FIG. 10.—Rat eye (retina) stained with fluorescent normal globulin. The holes and cracks are artefacts. The sclera shows auto-fluorescence. × 190

Discussion

The fluorescent antibody technique of Coons and Kaplan has in the past been used to study a wide variety of problems. These include work on basement membranes by Hill and Cruickshank (1953) and Cruickshank and Hill (1953) and the study of experimental glomerular nephritis by Mellors, Seigel, and Pressman (1955), Mellors, Arias-Stella, Siegel, and Pressman (1955), and Ortega and Mellors (1956). Humphrey (1955) was able to determine the origin of blood platelets and Cruickshank (1956) has attempted to locate the site of formation of anterior pituitary hormones. Witmer (1955) studied the local production of antibody in the eye after an intra-ocular injection of egg albumen.

It has been pointed out in a discussion of the technique (*British Medical Journal*, 1956) that interpretation of the specificity of staining may be difficult. This is especially so in the eye, where there is auto-fluorescence, particularly in the lens substance and sclera and to a lesser degree in the cornea and retina.

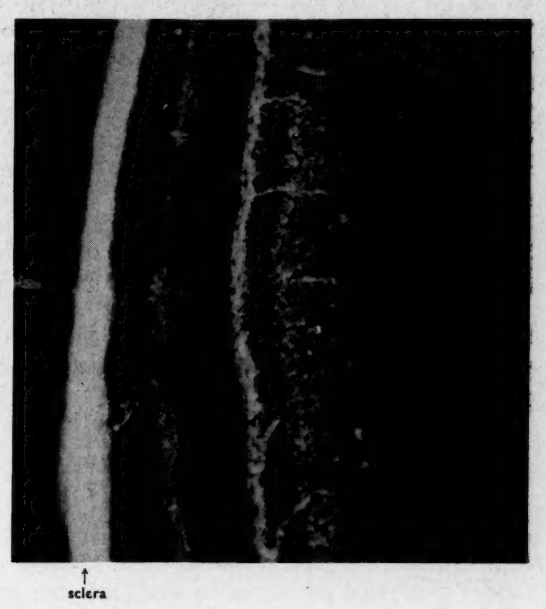


FIG. 11.—Rat eye (retina) stained with fluorescent ARGG. ×190

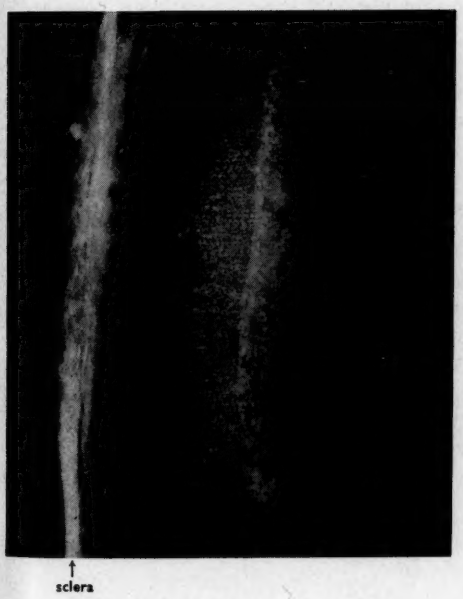


FIG. 12.—Rat eye (retina) stained with fluorescent ARGG after section had been treated with ARGG. ×190

Superimposed on this was some non-specific staining, which could not be removed by repeated absorption of the fluorescent globulins with heterologous tissue.

Hill and Cruickshank have shown that antiglomerular globulins react with basement membranes and reticular tissue elsewhere in the body.

In the present experiments, fluorescent ARGG reacted specifically with the glomeruli of rat kidney (Figs 1, 2, 3). In the rat eye, this antiglomerular globulin appeared to be taken up specifically by the lens capsule. It was not possible to differentiate any subdivision of the capsule into zonular lamella and capsule proper. Cruickshank and Hill (1953) pointed out that their serum reacted with reticular tissue but not with collagen. This would support the view that the lens capsule, although showing many similarities with collagen, is in fact different and resembles structureless basement membranes elsewhere in the body (Pirie and van Heyningen, 1956).

In the ciliary body and iris, there was staining of a reticular membrane which appeared to lie between the epithelium and stroma, extending into the latter.

A membrane in the smaller blood-vessels of the retina, optic nerve, and conjunctiva was stained, but in the ciliary body and iris no vessels were demonstrated, the general pattern of the staining had the appearance of connective tissue and could not be identified with any possible blood-aqueous barrier within the anterior uvea (Palm, 1951).

In the albino rats used, Descemet's membrane was difficult to demonstrate even in sections stained with haematoxylin and eosin or with periodic acid Schiff. This difficulty, combined with the presence of non-specific staining and auto-fluorescence, may account for the fact that the membrane was not clearly visible in sections stained with fluorescent ARGG.

The specific staining of these ocular structures would suggest that a common antigen is shared by them and by the glomerular basement membrane.

Summary

The application of the fluorescent antibody-antigen technique in ophthalmic pathology is discussed.

An antiserum to rat glomerular basement membrane was produced, and this was shown to react specifically with membranes in the ciliary body and iris and also with membranes in the small blood-vessels of the retina, optic nerve, and conjunctiva.

The lens capsule shared this antigenicity and would seem to resemble basement membranes elsewhere in the body.

I should like to thank Dr. A. G. S. Hill and Dr. D. G. Scott for much advice about the technique, Dr. J. Humphrey for a supply of fluorescein amine, and Mrs. A. Pirie for coupling the sera.

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SOEMMERRING'S RING*
A REVIEW AND THREE ILLUSTRATIVE CASES

BY

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A PERUSAL of the literature suggests that the ring-shaped tumour (*cristall-wulst*) of regenerating lens substance first described by Soemmerring (1828) is not uncommon but may pass unrecognized unless the pupil is very wide, a congenital or operative coloboma of the iris is present, or the ring has become dislocated (Figs 1 and 2). Not more than fourteen cases of dislocation have so far been published, although according to Guha (1951) the ring tends to dislocate easily, unlike the ordinary after-cataract.

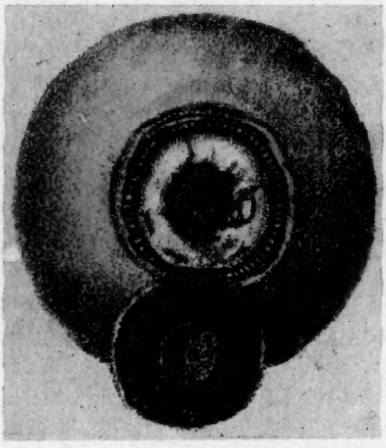

FIG. 1.—The ring of Soemmerring, showing the annular after-cataract in a *post mortem* eye with the cornea removed (from his original monograph, 1828).

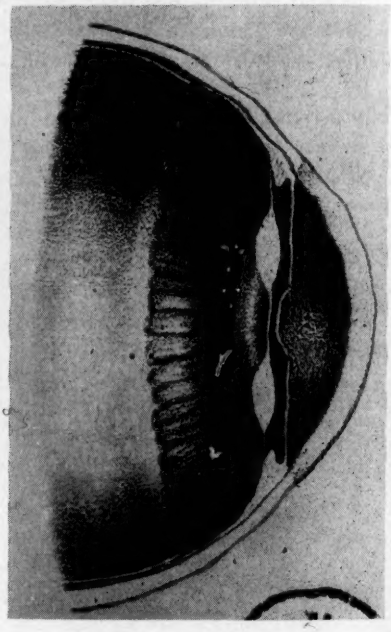

FIG. 2.—Soemmerring's ring in section (also from his original monograph, 1828).

Three cases of Soemmerring's ring have been encountered in the Leeds General Infirmary within the last year. In two of these the ring was noted *in situ* by virtue of an iris coloboma and good mydriasis; in the third an incomplete ring lay dislocated in the anterior chamber and was giving rise to symptoms.

Although comprehensive reviews of the condition have been given within recent years by Guha (1951) and Arruga (1953), some of the main points are worth repeating and enlarging.

* Received for publication December 12, 1956.

Formation.—Following discission for congenital cataract, Fukala's operation for myopia, penetrating injury of the lens, or extracapsular cataract extraction, lens fibres may be retained between remnants of the anterior and posterior capsules around a central aperture. Union of the anterior and posterior capsule protects the enclosed lens remnants from the aqueous, and lens fibres continue to proliferate from the subcapsular epithelium which extends to the inner surface of the posterior capsule. The ring-like tumour may occur in three forms:

(*a*) The primary encysted and secondary regenerating lens fibres produce a small, swollen pessary, sometimes relatively transparent and sometimes opaque, lying in the equator of the retro-iridial space or occasionally in a more central site.

(*b*) Irregularly-shaped lentoid masses are strung together in a ring or torus form by tenuous processes (Berliner, 1949).

(*c*) The ring is incomplete and is represented by a crescentic sausage. After extracapsular extraction in senile eyes the formation tends to be incomplete as the epithelial border above is often injured during anterior capsulectomy (Fuchs, 1933).

Youthful eyes, with greater regenerative activity in the lens substance, favour the formation of a complete and larger ring (Poos, 1931), as was shown in the animal experiments of Wessely (1910).

Sequelae.—When *in situ* the ring gives support to the periphery of the iris and the iridodonesis of aphakia is therefore absent or less obvious (Fuchs, 1933). It does not usually cause symptoms except in the case of:

(*a*) Protrusion of the ring beyond the edge of the pupil. Vision may then be obstructed.

(*b*) Dislocation, anteriorly into the anterior chamber, or posteriorly into the vitreous, or partly into both. The dislocation may be spontaneous or traumatic and is favoured by several factors, namely, formation of the ring at an early age, myopia, degenerative changes in the ring and a senile eye. The luxation is further facilitated by a weak, degenerate zonule. Apart from the disturbance of vision common to anterior and posterior dislocation, the anterior luxation may be followed by *uveitis* or by *secondary glaucoma*.

Rizzini (1955) describes retinal detachment in his case of traumatic posterior dislocation, but this association is probably fortuitous.

Pathology.—The formation of the ring has been described earlier in this paper and refers to events directly following extracapsular extraction (or lens discission) as a primary procedure, but the ring can also develop some time after division of a secondary membrane. Berliner (1949) suggests that, after the latter procedure, the capsular membranes curl and retract and with release of internal tension proliferation may begin again. Histologically, he continues, the epithelium may proliferate, not only lining the posterior capsule, but also growing around the torn edges of the anterior capsule and forming a lining of cells on its anterior surface. These cells may secrete

new hyaline material and, depending on the number of layers of epithelial cells, may form alternate layers of hyaline membranes.

The histological specimen taken from the case of dislocation (Case 3, Figs 5 and 6), which was reported on by Dr. Norman Ashton, illustrates the extension of epithelium to the inner surface of the posterior capsule. In the field illustrated, the epithelial layer was single but it showed reduplication and some vacuolated bladder cells in other areas. In the cortex, swelling of the lens fibres and granular bodies were present.

It is stated that degeneration of the encapsulated lens matter is common, with the formation of Morgagnian globules, and possibly at a later stage calcareous and even osseous changes.

It is interesting that a Soemmerring's ring was found histologically in an eye containing a Ridley lenticulus (Case of Mr. J. Foster—reported by Theobald, 1953). A late post-operative hypopyon iritis had occurred which was subsiding under treatment, but, as the visual prospects were poor and the other eye normal, it was deemed wise to excise the eye as being potentially "dangerous".

Differential Diagnosis.—The ring of Soemmerring is to be distinguished from the "lifebuoy" or disc-shaped cataract described by von Szily (1938) and others, to which it has a certain resemblance. Lifebuoy cataract is, however, a congenital condition believed to be due to aplasia of the nucleus or a secondary degeneration of the central area. There is no resemblance to Doyne's discoid cataract which is a congenital foetal nuclear opacity.

Treatment.—If the ring is *in situ*, no active treatment is indicated unless it extends centrally beyond the pupil margin and impairs vision. An ordinary discission would then meet the case.

Fuchs (1933) makes the important practical point that a capsulotomy to divide membrane blocking the aperture of a Soemmerring's ring should not extend peripherally to injure the lens fibres of the ring. If one extends the discission into the crystalline tumour, one again has to go through a period of swelling and resorption of lens substance, whereas the discission of the membranous portion creates a clear opening through which good vision can be at once obtained.

No record of operative treatment was found in the literature in cases of dislocation into the vitreous.

In one case in which the ring lay dislocated half in the vitreous and half in the anterior chamber, Tooke (1933) extracted most of the ring with Kalt forceps. He fashioned a conjunctival flap above, did a small von Graefe corneal section, fixed the eye by a Ziegler's needle which he thrust subconjunctivally into the nasal filtration angle, and grasped the ring with one forceps blade in front and one behind, both meeting at the aperture of the ring.

In the case of anterior dislocation recorded by Jess (1931), the ring was extracted by keratotomy with capsule forceps.

The anteriorly dislocated partial ring illustrated here was extracted with Arruga forceps (in two halves as the crescent broke), through an *ab externo* incision sutured as for a McLean's extraction. In this instance the lens mass was grasped directly and with success, but as an alternative, withdrawal might be effected by transfixing with two cystitomes.

Case Notes

Case 1, a woman aged 20, gave a history of injury to the right eye by a boy's finger in 1940, followed by traumatic cataract, abscission of iris prolapse, and conjunctival flap repair. In 1941 she had intermittent right convergent squint, and in 1943 a right capsulotomy and anterior synechiotomy. She did not attend again until 1956, when she complained of headaches particularly in bright light.

Visual Acuity: Right eye perception of light, with +8 D sph., +2·5 D cyl., axis 105°.
Left eye 6/6, with +0·25 D sph., +0·25 D cyl., axis 80°.

In the right eye there was an old penetrating corneal wound, an incomplete irregular ring of opaque greyish-white lentoid masses, with capsular remnants and Elschnig's pearls around a central opening within the ring, and posterior pigment synechiae. The eye was quiet (Fig. 3).

The right eye illustrated an incomplete symptomless Soemmerring's ring *in situ*, visible within a widely dilated pupil.

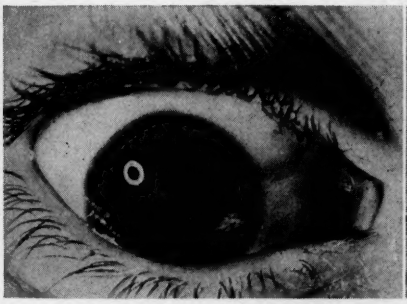

FIG. 3.—Case 1, irregular Soemmerring's ring *in situ*, the sequel to a penetrating injury. The small circle towards the left is the camera reflex.

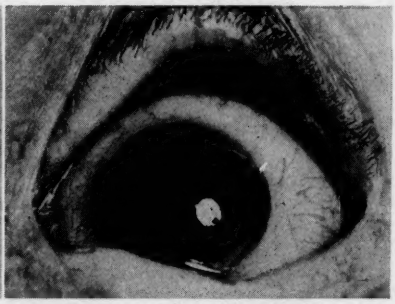

FIG. 4.—Case 2, part of a Soemmerring's ring visible within the site of iridectomy above. This followed extracapsular lens extraction. The camera reflex is towards the right.

Case 2, a man aged 90, gave a history of right and left extracapsular lens extractions (no details available), and right and left capsulotomy in 1942. In 1956 he attended with trichiasis.

Visual Acuity: Right eye 6/9 pt, with +11 D sph.
Left eye 6/12 pt, with +12 D sph., +1·5 D cyl., axis 20°.

In the left eye a greyish-white opaque sausage-like mass of lens matter was noted arching into view from behind the iris in the area of a previous iridectomy, peripherally situated above, and concentric with a clear central aperture in some thin capsular remnants (Fig. 4). It represented an incomplete symptomless Soemmerring's ring *in situ*.

Case 3, a woman aged 79, gave a history of high myopia and diabetes. In 1900 she had had an operation on the left eye (? discission, no details available). In 1912 she had had a retinal detachment of the left eye. In 1930 she was seen by Mr. Rycroft, and an operation for retinal detachment was not advised. In October, 1954, a "white lump"

was noticed by the patient in the left eye, which became occasionally painful. In February, 1955, she saw Mr. Lloyd at Bradford who, according to the patient, advised against any operative treatment on diabetic grounds.

Visual Acuity (August, 1955): Right eye 2/60, with −20 D sph., −3 D cyl., axis 160°.
Left eye no perception of light.

In the right eye nuclear cataract with choroido-retinal degeneration was seen.

In the left eye a large crescentic sausage-like mass of lens matter was lying horizontally in the anterior chamber, free at the temporal extremity but still attached to a capsular membrane at the nasal side. The pupil was partially obstructed by the lentoid mass. There was early band degeneration with oedema of corneal epithelium, folds in Descemet's membrane, and corneal vascularization (Fig. 5). The fundus reflex was dim and the choroido-retinal degeneration barely visible.

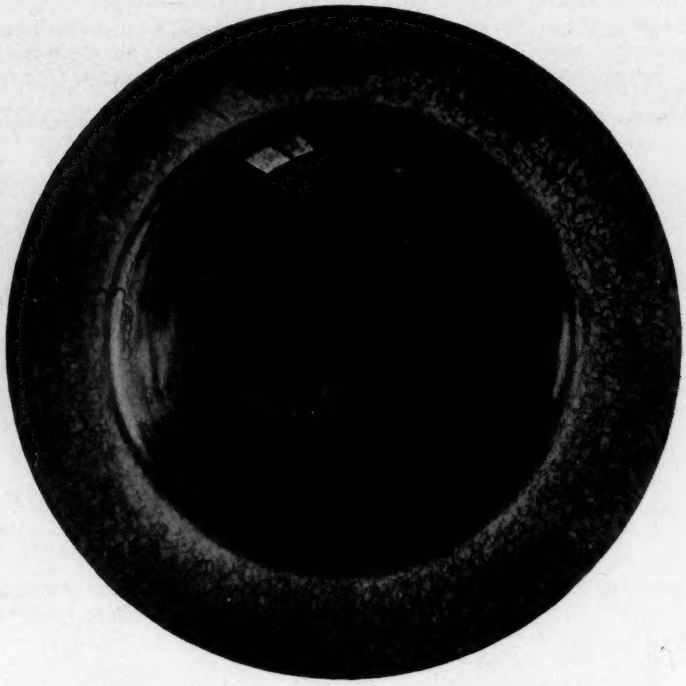

FIG. 5.—Case 3, incomplete Soemmerring's ring dislocated into the anterior chamber. The dislocation was spontaneous.

Ocular tension in the left eye was 22 mm. Hg (Schiötz).

The case demonstrated an incomplete Soemmerring's ring which had dislocated spontaneously into the anterior chamber. The symptoms were attributed partly to an irritative uveitis and partly to corneal breakdown.

It was decided to extract the lens matter and, if that should fail, to excise the eye.

Mr. J. Foster performed the extraction by the McLean route in January, 1956, and so far the eye has been reasonably comfortable, assisted by simple emollients.

The histological appearance is shown in Fig. 6.

FIG. 6.—Section of lens matter removed from the anterior chamber in Case 3, showing extension of subcapsular epithelium to cover posterior surface. The break in continuity is the former site of attachment of the "ring" to capsular fringes behind the iris. Haematoxylin and eosin. ×65.

Summary

(1) Soemmerring's ring is a not uncommon form of after-cataract, but is only clinically recognizable under certain conditions. It is usually symptomless.

(2) Dislocation of the ring is rare but it can disturb vision or lead to secondary glaucoma or uveitis.

(3) Only two cases of dislocation were found in the literature to have undergone operation. A third is described in this paper, which also includes a general review of the subject.

My thanks are due to Mr. John Foster and Mr. George Black for their kind interest and for the use of their clinical cases; also to Mr. Pegg, Photographic Department, Leeds General Infirmary, for the clinical photographs; and to Mr. Blackledge, Photographic Department, Leeds University, for the microphotograph.

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AN ANTERIOR CHAMBER LENTICULAR IMPLANT*

BY

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London

THE introduction of artificial intra-ocular lenses has been proved to be a practical possibility and has gone far to mitigate the disadvantages of aphakia especially in cases of monocular cataract. Intra-ocular acrylic lenses have now been in use for 7 years and there is no doubt that the eye can tolerate pure polymethyl methacrylate for at least this time, for satisfactory cases, once the initial irritation has passed, remain free from inflammation and symptoms or signs of foreign body reaction (H. Ridley, 1952, 1956). The operation, though not in principle difficult, has in practice not always proved straightforward, the two main complications being slow convalescence due to reactionary iritis and late dislocation of the lenticulus. Especial care is necessary to remove all or almost all of the cortical remnants and to avoid any damage to the very thin posterior capsule on which the stability of the lens depends. Surgical failure in either of these respects almost inevitably leads to a distressing result. Extracapsular extraction with insertion of an intra-ocular acrylic lens comprises two operations in one, and any operative error is likely to be heavily penalized.

The difficulties of intra-ocular acrylic lens surgery led Strampelli (1954) and later Schreck (1955) and Scharf (1955) to devise simpler techniques and to employ acrylic implants placed in front of the iris. A lens in the anterior chamber is not so ideally situated as one in the natural position, but it has certain advantages. It can be employed after intracapsular extraction since its large diameter prevents posterior dislocation. In extracapsular cases late capsulotomy is simple and differs little from such an operation after plain extracapsular surgery, for there is a space between the back of the lens and the posterior capsule. Two-stage surgery presents no difficulty, since posterior synechiae are of no practical importance and do not impede late insertion of the lens. In most cases a fair estimate of the refraction can be made and, if the manufacturer is given the back vertex power and vertex distance of the aphakic correction, and in monocular cataract the refraction of the other eye, a special anterior chamber lens can be ground to suit the particular case. Finally there is a smaller area of contact between the implant and the iris, and less post-operative iritis is to be expected, especially if the extraction has been intracapsular or if an adequate interval

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has been allowed before insertion of the implant after extracapsular extraction.

Various patterns of lens have been designed by Strampelli (1954) and others but an ideal design has not yet been evolved. There seems at present to be a tendency to use simple implants about the diameter of the anterior chamber in length and some 6 mm. in width. Such a lens is easy to insert and only a small corneal incision is necessary, but it is possible for such an implant to twist on its longitudinal axis or to slip out of the line of the pupil unless the exact optimum length can be correctly assessed before insertion: and this is no simple problem. Furthermore, if the patient is young, the fit may become less accurate with growth of the eye.

To overcome these difficulties and to produce a lens with a very high degree of stability, it was decided to design an implant consisting of a central lenticulus supported by three legs (or arms) arranged to provide wide triangular support (Fig. 1). Two of these legs subtend an angle of 33° each from the vertical meridian below, while the third lies on the vertical meridian above. The legs curve backwards so that when their tips lie on the iris periphery the lens is supported approximately mid-way between the cornea and pupil with gaps of about 1 to 1·5 mm. between the front of the lens and the cornea and between the back of the lens and the posterior capsule. The posterior curvature can be varied by the manufacturer to suit the refraction of the particular eye for which is it intended. The diameter of the haptic can also be varied and it is advisable to have several sizes available before undertaking the insertion.

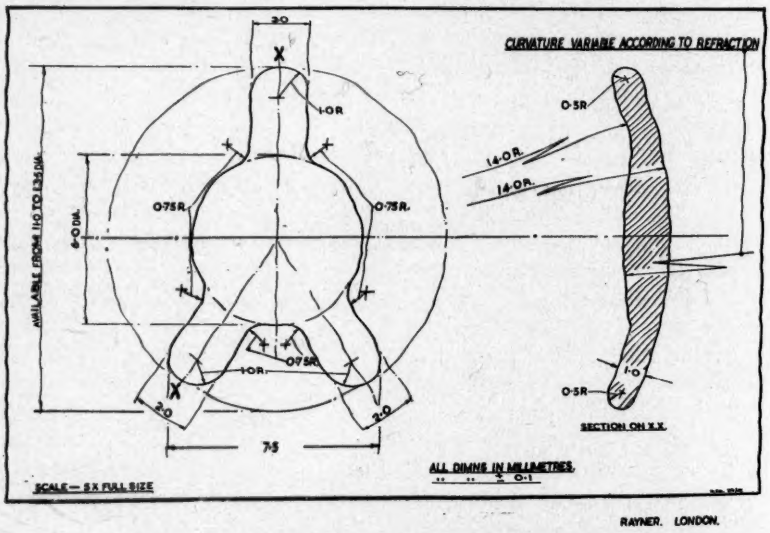

FIG. 1.—Anterior chamber lenticular implant (author's pattern).

Sets of such lenses in different haptic diameters (Fig. 2) are now available and will in future be sterilized by the makers in accordance with the directions given by Mr. Frederick Ridley (1957).

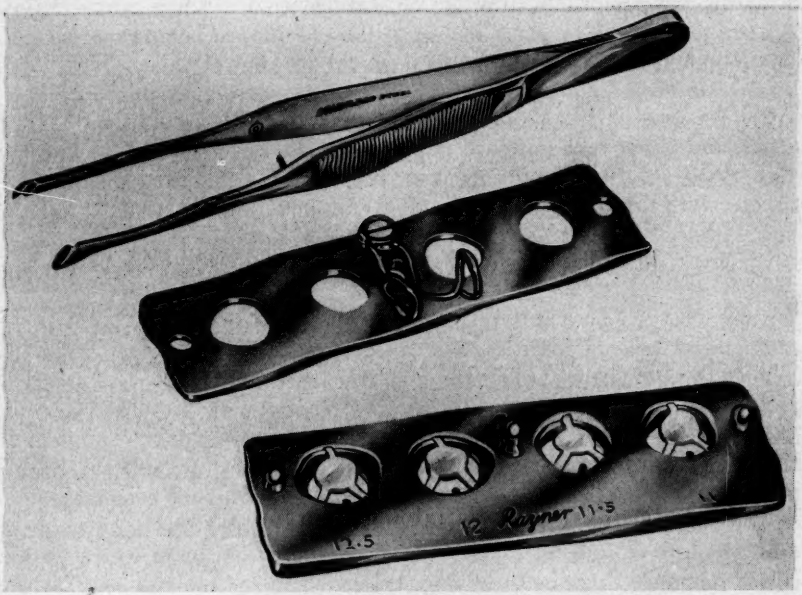

FIG. 2.—Insertion forceps and set of anterior chamber lenticular implants of various haptic diameters.

An anterior chamber implant of this pattern is comparatively easily inserted. A satisfactory method of judging the size to be employed has not yet been evolved, but an estimate may be made by measuring with calipers the diameter of the limbus (from white to white) in the vertical meridian and trying an implant with a haptic 0·5 mm. greater. If much difficulty is encountered when inserting this, one size smaller may be used, for the broad triangular supports do not require firm pressure in the region of the angle to maintain the position. A corneal incision of about 8 mm. is made with a von Graefe knife so that a corneo-scleral lip is left. A keratome incision, being narrower internally than externally, is less suitable. The lens, grasped with special forceps (Fig. 3) by its upper projection, is directed through the wound, one of the lower

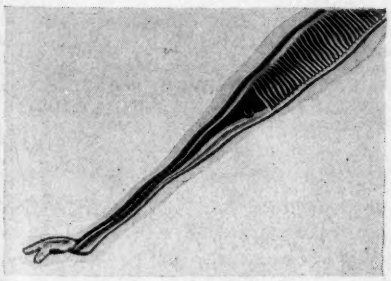

FIG. 3.—Insertion forceps. The implant is held in a groove at an angle of 45° to the line of the forceps.

legs being inserted before the other. Little difficulty should be encountered in siting the two lower legs if the pupil is small, but in eyes damaged by trauma some manipulation may be necessary to set both legs on the front of the iris and equidistant from the vertical meridian. When the two lower legs are seen to be in place the upper may be slipped behind the corneo-scleral lip and the wound closed with or without sutures.

There is little tendency for the eye to react sharply to this operation, partly because it is generally, though not necessarily, performed in two stages, and partly because much less of the prosthesis is in contact with the iris. Some exudates usually form on the acrylic surfaces but they quickly disperse with the aid of cortisone. It is simple to perform a later posterior capsulotomy should it be required. The appearance of the eye should be satisfactory, for the margin of the lenticular portion is concentric with the pupil.

It may be asked whether such an anterior chamber implant with its comparative ease of insertion and safety from dislocation supersedes the original intra-ocular acrylic lens which in favourable circumstances has provided such good results. The proper place for an artificial lenticulus must surely be where Nature intended the crystalline to be. The optics of an eye are restored most closely to normal when the artificial lens is behind the iris, and in eyes which have no defect except cataract the original pattern or some slight modification would seem ideal. There are however many eyes which have suffered injury or past inflammation, or in which growth is not complete, and in them the anterior chamber implant is safer and superior.

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SAFETY REQUIREMENTS FOR ACRYLIC IMPLANTS*

BY

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REDMOND SMITH (1956) produced further evidence for an irritant, Cetrimide, introduced at the time of operation being the cause of inflammatory reaction when an acrylic lens is inserted into the eye.

Binkhorst and Flu (1956) proposed the use of ultra-violet rays for sterilising intra-ocular prostheses. Their objection to the use of detergents does not take into account the fact that these substances differ greatly in their physico-chemical behaviour with regard to acrylic material, and they offer no method of rendering the lens chemically clean after manufacture. The process of irradiation with ultra-violet light is open to several objections. First, it is not certain that all spores will be destroyed. Also, it is known that ultra-violet light of wavelength 2,537 Å is strongly absorbed by polymethyl methacrylate (Fig. 1).

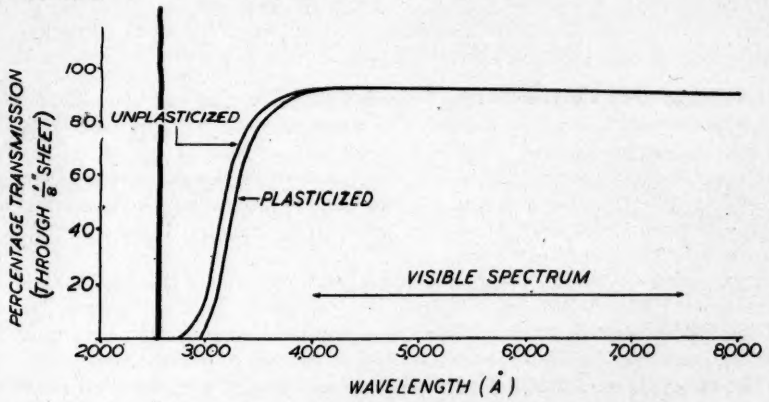

FIG. 1.—Perspex light transmission, visible range. Superposition of emission curve of ultra-violet tube recommended by Binkhorst and Flu (2537 Å) upon the absorption curve of polymethyl methacrylate. (Taken from "Perspex" Acrylic Materials, I.C.I. Plastics Division). The material is virtually opaque to ultra-violet of this wavelength.

This type of ultra-violet radiation is known to degrade acrylic materials with the production of monomer, and the process is accelerated by any rise in temperature. The intense absorption of the radiation by the polymer will cause most of this monomer to be liberated near the surface of the polymer. More evidence is needed to show that a significant amount of the monomer,

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which is highly irritating, is not formed in the surface layers of the lens where it is most easily accessible. It is felt that the apparatus recommended by Binkhorst and Flu does not provide sufficient guarantee against depolymerization by the ultra-violet, especially in view of the overheating which may be brought about by the insulation of the acrylic lens from the air stream by the quartz capsule. For these reasons it is thought that the method described by Binkhorst and Flu may not be sufficiently rigorous.

Materials and Manufacture

Properties of the Material to be Used.—Any material to be permanently inserted into the eye, or indeed elsewhere in the body, should have the following characteristics: it should be insoluble in water, inert to all body fluids, and should never give rise to tissue sensitization; it should have the physical properties required for its proposed use, and it should be able to be shaped to the required form. Some 1,500 patients fitted with contact lenses at the Contact Lens Department, Moorfields Eye Hospital, have worn lenses made from Transpex I regularly for periods up to 5 years, and in no case is there reason to believe that these lenses have provoked an allergic reaction in the eye. Pure polymethyl methacrylate is available under the trade name Transpex I (I.C.I.). It will be referred to either as polymethyl methacrylate or as acrylic. Other commercial materials based upon polymethyl methacrylate are available. Many of them contain fillers and plasticizers or for other reasons do not comply with the rigid standards of purity and full polymerization required for our purpose.

Conditions to be Observed during Manufacture.—The material, as received from the manufacturers, must be washed with warm distilled water to remove traces of gelatine coating adhering to it.

During manufacture no part of the material must be exposed to a temperature exceeding 140° C., above which point depolymerization sets in liberating the highly irritating monomer within the polymerized material from which it will escape into the tissues for a long time. It is almost impossible to detect this change and the only safe procedure is stringent exclusion of the possibility of its occurrence. This means that, during any moulding process, control by an efficient thermostat must be provided, and any machining and grinding must be undertaken under conditions securing effective cooling of the material.

The materials used in any process such as polishing or grinding must not react chemically with the acrylic, or be absorbed by it. Either they must be able to be removed entirely by subsequent treatment or they must be harmless should a trace be introduced into the tissues.

Cleaning and Sterilizing after Production.—When manufacture has been completed we have to clean the surface and sterilize it. The principles underlying this should be to use, as far as possible, chemicals which do not react in any way with the acrylic and which contain only physiologically acceptable ions. The contaminants likely to be found are grease from polishing materials or from handling, aluminium oxide in the form of emery used for grinding, and sintered iron oxide, in the form of rouge, used for polishing.

Physical Chemistry of the Problem

Detergents

(1) The physico-chemical behaviour of detergents towards acrylic is a relatively unexplored subject, but the reaction would be expected to depend upon the general ionic character and molecular structure of the detergents. Cationic detergents are more likely to become absorbed on to the surface than other types, because the surface of polymethyl methacrylate can be acid due to the presence of small amounts of copolymerized methacrylic acid. This would be expected to bind amines fairly strongly, and could be the explanation of the observed strong absorption of Cetrimide. Such cations would nevertheless desorb easily in contact with excess sodium.

(2) Anionic detergents should be free from this possibility of absorption and it would be preferable to use a product such as pure sodium lauryl sulphate.*

(3) Non-ionic detergents might well penetrate fairly easily into the surface layers and they should be avoided.

(4) In critical work, distilled water should be used both to dilute detergents and to wash them away. Tap water forms a detergent scum very easily. Repeated changing of distilled water for washing is preferable.

Hydrochloric Acid

This will diffuse in and out fairly quickly, and it is very doubtful if it would be totally removed by soaking in caustic soda subsequently. If used in high concentration, 30 per cent., a considerable proportion would be un-ionized and this would penetrate easily. While it is broadly true that acrylic is inert to HCl, it is doubtful whether treatment with 30 per cent. HCl might not tend to hydrolyse the material to polymethacrylic acid, especially at the surface. This surface hydrolysis would render the material more liable to adsorb and absorb other materials such as detergents. It has formerly been proposed (Ridley, 1954) to use concentrated hydrochloric acid to remove the sintered iron oxide in the rouge used as a polishing agent. In view of this criticism it is desirable to use an alternative product, such as "Cerirouge" (Thorium Ltd.), as a polishing medium. Cerium oxide is almost entirely inert, and there is no reason to suppose that, in such minute quantity as we are considering, it would have any harmful effect if traces of it were introduced into the eye or other tissues. In the manufacturing process to be described, this difficulty is avoided altogether, since the lenses are produced by pressing between metal dies and no grinding or polishing materials are employed.

* Available as "Empicol" LZ from Marchon Products Ltd.

Caustic Soda

This substance is intensely anionic and will diffuse into acrylic little if at all. It will not harm the material in any way.

A Method of Preparing Acrylic Prostheses

To remove Traces of Grease.—The material will have been cleaned thoroughly by polishing with a clean soft material which has been washed and which contains no impregnated polish. If the lens has been produced by pressing, the material can be protected by latex rubber during the necessary subsequent handling to perfect the edge, and this can be polished with a dry clean bob of linen or swansdown, no grease or polish being used. This technique is recommended.

Notwithstanding that the lens is now mechanically clean, the possibility that a film of grease, trapping dirt and possibly bacteria, is present on the surface must be eliminated, and with suitable precautions it seems desirable to use a detergent for this purpose. Sodium lauryl sulphate 0·1 per cent. at 40° C. for 5 minutes has been shown to remove even the beeswax compound employed in polishing waxes. Its efficacy should be checked for each method of manufacture employed. The lens is now thoroughly washed in distilled water for several minutes to remove surface traces of the detergent.

Sterilization.—Hobbs and Wilson (1942) and Tilley (1946) have shown that caustic soda 10 per cent. at 30° C. for one hour will completely sterilize even the spores of *B. subtilis* (Fig. 2, opposite). If the lenses are mounted in carrying racks made of acrylic and this assembly is fixed within a screw-cap polythene container, the whole assembly can be exposed to 10 per cent. caustic soda without any harmful effect. Metals should be avoided because they are liable to be attacked, and other plastic materials should be avoided because of the risk that they may contain deleterious fillers or plasticizers which may pass into solution during storage. After the assembly has been sterilized, it is removed from the caustic soda bath, emptied, and refilled with caustic soda 0·1 per cent. This concentration is fully protective at room temperature and constitutes a safe storage medium (Fig. 3, opposite). The cap is screwed down tightly and sealed with Sellotape. It is now ready for storage and if necessary for despatch by post.

The possibility that the caustic soda solution might deteriorate during storage, on account of absorption of carbon dioxide from the air through the polythene container or by reason of its fixation by traces of methacrylic acid known to be present in the surface of acrylic materials, was investigated. The screw-cap container was three-quarters filled with 50 ml. nominal 0·1 per cent. caustic soda which on precise analysis proved to be 0·1098 per cent. This was kept in an incubator at 34° C. for 5 weeks. At times it was stood upside down, and from time to time it was shaken thoroughly. This

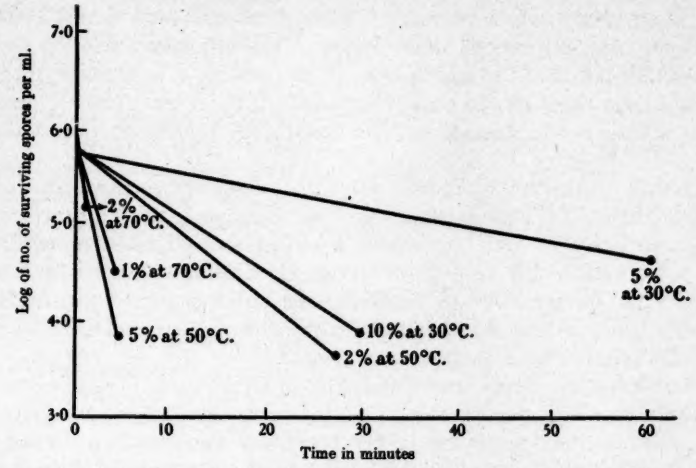

FIG. 2.—Rate of death of spores of *B. subtilis* when submitted to different concentrations of sodium hydroxide at different temperatures (Hobbs and Wilson, 1942).

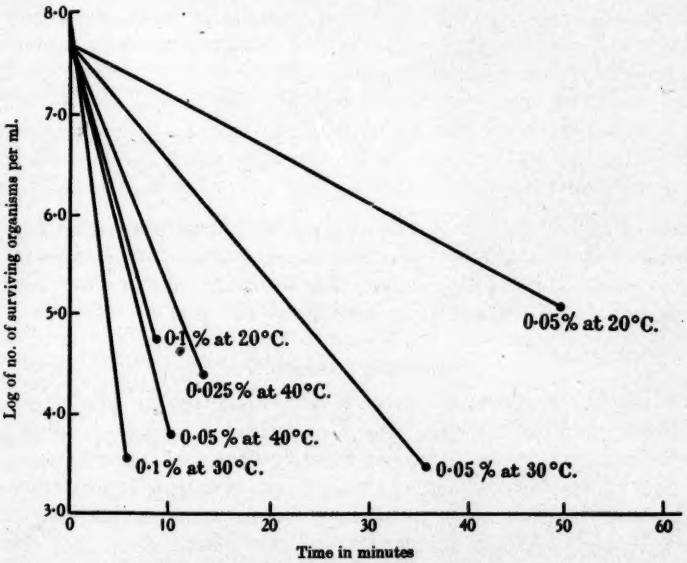

FIG. 3.—Rate of death of *B. coli* when submitted to different concentrations of sodium hydroxide at different temperatures (Hobbs and Wilson, 1942).

rather stringent test showed that the screwed-down lid is completely watertight. At the end of this trial period the concentration of NaOH was found to be 0·1031 per cent. as compared with a wax-lined sealed bottle kept at

room temperature which showed a loss of caustic soda from 0·1098 to 0·1060 per cent. during the same period. The difference between the two samples, 2·9 per cent., is significant. It is possible that a trace of carbon dioxide passes through the polythene wall. It is certain that 0·1 per cent. caustic soda is a safe storage medium for several months at room temperature.

A further control, in which the polythene container was two-thirds filled with disks of methyl methacrylate one mm. thick, giving a total surface area of approximately 700 cm^2., was similarly filled with 40 ml. nominal 0·1 per cent. caustic soda and kept for 5 weeks at incubator temperature. This showed a fall from 0·1098 to 0·097 per cent. in 5 days and from 0·097 to 0·060 per cent. in 5 weeks, which indicates a progressive release of acid or fixation of alkali by the methyl methacrylate.

Two observations seem pertinent. The small amounts of acrylic material used in the stand supporting the lenses and in the lenses themselves can have no significant effect upon the concentration of the caustic soda solution. The possibility that methyl methacrylate, in the presence of dilute caustic soda, liberates progressively a minute amount of co-polymerized methacrylic acid is interesting and may well merit further study. The amount is very small. If, however, the equivalent amount of methacrylic acid were liberated from an acrylic implant it might be relevant if it were not eliminated from the eye. All the evidence is against this possibility having significance, since the reactions which have been observed when these lenses have been introduced have been greatest in the early stages. To minimize this possibility the lenses should be stored in 0·1 per cent. caustic soda for 3 months before being re-sterilized and issued for use.

Gloves.—Both in sterilizing and subsequently at operation, it is important to remember that rubber gloves must not be treated with talcum or other dusting powder. In handling caustic soda solutions, rubber gloves, sterilized by boiling in sterile distilled water, should be used wet.

Procedure at Operation

The equipment reaching the surgeon will be a sealed polythene container containing four lenses in a rack (Fig. 4, opposite), a hard glass tube of sodii. bicarb. 0·5 per cent. in distilled water which has been autoclaved after sealing, and a pair of dry, heat-sterilized lens forceps in a sealed glass tube. The container and the glass tubes are placed in spirit to sterilize them externally and are then dried with a sterile towel and placed upon the operating table.

The procedure is as follows:

(1) Remove the screw-cap and, holding the centre pin with the index finger, pour out the 0·1 per cent. caustic soda.

(2) Open the ampoule and pour the sodii, bicarb. 0·5 per cent. into the container; replace the screw-cap firmly.

(3) Shake thoroughly and leave to stand upside down, so that the lenses and their racks are fully immersed, for 5 minutes.

(4) Remove the screw-cap and pour out the sodii. bicarb. solution.

(5) Lift off the retaining plate. Pick up the lens with the special lens forceps, which have been boiled in distilled water and subsequently sterilized by dry heat, and insert it directly into the eye.

The forceps must not be dipped in any detergent and it is unnecessary to dip them in any fluid whatever. The lens in its tray is sterile and wetted with only a trace of 0·5 per cent. bicarbonate solution. Contamination of either the lens or the forceps during this manoeuvre must be avoided.

Similarly, the special forceps should be kept dry and apart from any possibility of contamination on the table before use.

If rubber gloves are worn by the surgeon or any of his assistants they must not be dusted with talc or any other powder. Cotton gloves or no gloves are preferable. The possibility of introducing talc or other dusting powder into the eye must be excluded absolutely.

Attention may be drawn at this point to the need for the greatest care to be exercised with regard to the anterior chamber wash-out. Relatively large volumes of wash-out are often used in the Harold Ridley operation. The saline should be freshly made up with pyrogen-free distilled water, and should be a Ringer solution such as may be prepared with British Drug Houses tablets No. T.13867.B., one tablet per 540 ml. of water. The solution should be autoclaved. Alternatively, a sterile Ringer solution made up with pyrogen-free distilled water (*e.g.* Allen and Hanbury Sterivac No. 9: 500 ml.) may be used. The temperature of the irrigating fluid should be 37° C. (98·4° F.), and the irrigation apparatus should be free from foreign particles, detergent, or other contaminants. A Luer Lock glass syringe coated with Silicone grease with a

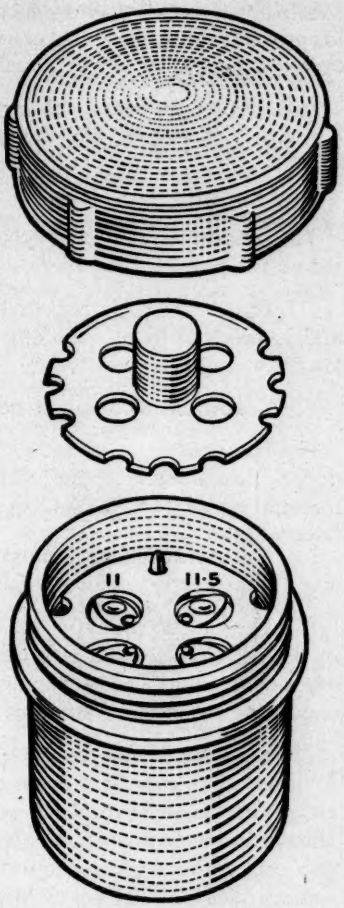

FIG. 4.—Container and method of transporting acrylic intra-ocular lenses (Messrs. Rayner). Strampelli lenses are illustrated. The lower diagram shows the polythene container in which is an acrylic stand carrying four lenses in counter-sunk recesses numbered to identify the four different lenses submitted in each case. Above this is the retaining plate which lies over the lenses localized by a centring pin. The central boss is so designed that, when the retaining plate is in position and the screw-cap illustrated above is screwed down to its flange, all slack in the assembly is taken up and the lenses are localized, but not gripped or in any way distorted.

metal cannula, washed in distilled water and sterilized by dry heat, is preferable to apparatus consisting of rubber and metal tubing which may hold foreign particles or fluids, cannot be fully inspected, and cannot be sterilized by dry heat.

Disposal of Equipment.—When the operation is completed the unused lenses are replaced in their rack, and the empty container is closed and returned to the makers.

Discussion

The procedure laid down is believed to satisfy the requirements defined in the earlier part of this paper:

(1) The material, polymethyl methacrylate, Transpex I (I.C.I.), is inert and is believed to be incapable of evoking a sensitization response in the tissues.

(2) Conditions to be observed during manufacture are laid down.

(3) The process of cleaning described removes any contamination introduced during manufacture without incurring the possibility that harmful material may be carried into the eye.

(4) The sterilizing programme is stringent and the conditions of storage give full protection against infection.

(5) The caustic soda, 0·1 per cent., used for storage is instantly destroyed by 0·5 per cent. sodium bicarbonate introduced in great excess. The resulting ions, sodium and carbonate, are in less than their normal physiological concentration in the tissues, while the bicarbonate in solution is harmless.

(6) We are left with the possibility that during storage some of the caustic soda solution may have been absorbed by the acrylic. The material can absorb up to 0·5 per cent. by weight of water. It is thus possible that, for a Harold Ridley lens weighing about one-tenth of a gramme, one two-millionth part of a gramme of caustic soda might be left in the lens after washing with sodium bicarbonate; for a Strampelli lens the figure would be even less. This minute trace of caustic soda would diffuse out very slowly; the sodium ion is harmless, and the hydroxyl ion will be trapped instantly by the 0·18 per cent. of sodium bicarbonate normally present in the tissue fluids and rendered harmless as carbonate.

It is thought that this rigorous method of manufacture, cleaning, sterilization, and ultimate surgical use may remove many of the disadvantages that have hitherto attached to the use of acrylic implants in ophthalmology.

Summary

(1) The properties necessary in a material to be used as an implant in the eye or other tissues are defined.

(2) Conditions of manufacture necessary to ensure that the prosthesis produced is safe are laid down.

(3) The physico-chemical behaviour of acrylic material is examined and a method of cleaning and sterilizing the prosthesis is described.

(4) A method of storing the prostheses in a special rack immersed in 0·1 per cent. caustic soda in a screw-cap container is described.

(5) The technique of employing this equipment in the operating theatre is detailed.

(6) Emphasis is laid upon the use of dry forceps, not contaminated with any detergent or other antiseptic, to place the prepared lens directly into the eye, and upon the avoidance of any possibility of contamination with talc or other glove powder.

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THE RIDLEY LENS IMPLANT*

BY

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THIS report is based on 84 cases. The youngest patient was 9 years old and the oldest 80 years at the time of surgery. The first operation was done in November 1951, and the last in December 1955.

Material

This series of cataracts includes eighteen traumatic, three complicating heterochromic cyclitis, one congenital, and the rest of indefinite aetiology—so-called senile cataracts (though several of these patients were only 40 years old)—and probably including cataracts due to contusions and other physical and toxic causes.

They were all unilateral except the one case of congenital cataract and two cases in the senile group. However, a further thirty cases in the senile group had very slight changes in the second eye at the time of operation, but still had a visual acuity of 6/6 or better. Of these thirty cases, eight have shown a further deterioration in the unoperated eye, so that one has had a second implant after 2 years and four others will require the second eye to be done shortly. One case had had a left extraction in 1949, as the right eye had early changes which, it was thought, were likely to progress rapidly. However, when seen by me in 1952 the unoperated eye still had a visual acuity of 6/6 ptly. As an extracapsular round-pupil extraction had been done, a lens implant was possible. The visual acuity to-day, 4 years later, is right still 6/9+, and left 6/5.

Results

Of these 84 cases, twelve were failures for probable causes to be discussed below. This seems a high percentage, but includes six or seven cases of an experimental nature where the patient was warned a good result might not be obtained.

Of the remainder, thirteen cases obtained 6/5 visual acuity with correction; 23—6/6; 23—6/9; six—6/12; four—6/18; two—6/24; and one—6/60.

The last had extensive retinal degenerative changes.

The two with 6/24 had macular lesions: one, a "hole" of unknown aetiology, the other a lesion caused by an intra-ocular foreign body that had impinged on the macula before falling back into the vitreous.

The four with 6/18 included one case of heterochromic cyclitis in which the eye had been blind for nearly 40 yrs and after surgery showed a probable macular lesion and a rather hazy vitreous. The other eye, however, had

* Received for publication December 31, 1956.

6/9 vision and the patient is delighted with the result. Two others with 6/18 were cases of traumatic cataract and included corneal damage so that a near central leucoma complicated the issue. The fourth turned out to have had unilateral high myopia.

The six cases achieving 6/12 vision included one of heterochromic cyclitis; this eye had been blind for 10 yrs, and there was a fair degree of vitreous haze. The other five cases also showed various degrees of vitreous haze and posterior capsular opacities. It is expected that some of these will improve and in others it is anticipated that a posterior needling will have to be done.

Technique

The surgical technique has been slightly modified over the years. The following points indicate the present procedure. Premedication includes Diamox 500 mg. and chlorpromazine 50 mg. the night before and 2 hours pre-operatively. I prefer the eye to be as soft as possible. Topical Decicaine 1 per cent., homatropine 5 per cent., and cocaine 3 per cent., with retrobulbar procaine 4 per cent., or xylocaine 2 per cent. with epinephrine and hyalase are used for mydriasis and local anaesthesia. Lid akinesia is obtained by the usual methods.

A lateral canthotomy is done routinely. Apart from allowing a wider exposure of the eye, I believe it helps to inhibit any tendency to close the lids tightly in the post-operative period. A 3 to 4-mm. conjunctival flap is raised by scissors dissection before cutting the section. With the eye very soft, cutting a large (180°) von Graefe section without damaging the iris can be difficult. I therefore prefer to cut a smaller section and enlarge with scissors to the 3 to 9 o'clock diameter.

Two double-armed 6 × 0 silk sutures, with Grieshaber or Jameson Evans needles, are used to insert four edge-to-edge sutures so that when tied the result is two mattress-sutures on edge.

A peripheral iridotomy at 12 o'clock is done next. For the capsulectomy I prefer to use a cystitome to cut as large a flap of capsule as possible. It is then completed with forceps. I have adopted this procedure to remove as much of the anterior capsule as possible. I have not found forceps capsulectomy by itself to give an adequate removal of the anterior capsule, and occasionally, with a tough capsule, weak zonule, and blunt toothed-forceps, an intracapsular extraction is unintentionally done. For a similar reason I hesitate to pull on remaining firmly-attached tags of capsule.

When the acrylic implant is being inserted the corneal flap is held well up with fine non-toothed forceps, so that the endothelium is not rubbed as the lens is introduced (Fig. 1, overleaf). The lens, held by a pair of straight iris forceps, is pushed well under the iris towards 6 o'clock until the largest diameter is engaged in the pupil. It is then slightly withdrawn so that the optical axis is judged to be a little above the normal pupillary centre. In

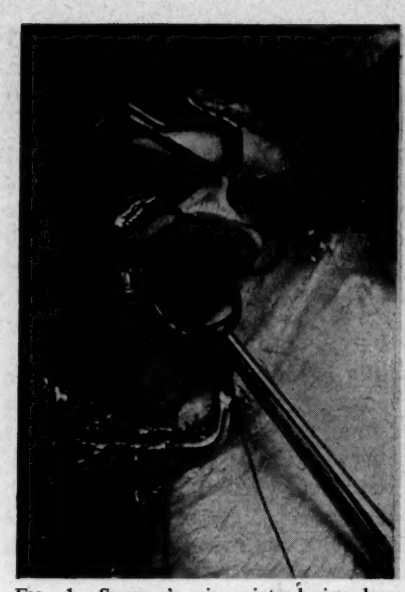

FIG. 1.—Surgeon's view, introducing lens. Note conjunctival-corneal flap held well up by non-toothed fine forceps, whilst acrylic is fixed by iris forceps. Magnified iridotomy is visible through lens, which in this case is the experimental larger type mentioned in the text.

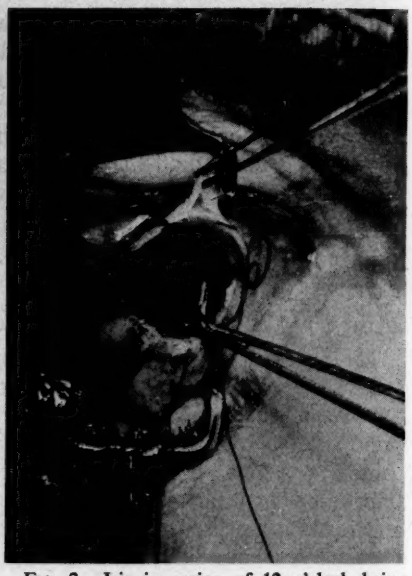

FIG. 2.—Iris in region of 12 o'clock being drawn round the lens. Note conjunctival-corneal flap now fixed by assistant. Forceps that had been holding flap now used as a probe to steady lens.

this manoeuvre the iris moves up with the lens so that the largest diameter is not disengaged. An assistant then takes over the corneal flap whilst the non-toothed fine forceps that had been holding it are applied with the jaws closed to press as a probe near the centre of the lens to steady it (Fig. 2). The iris forceps that had been holding the lens itself are then released. The iris about the 12 o'clock meridian is picked up by these forceps and pulled around and over the lens, thus completely covering it. I prefer forceps to Ridley's iris spike to pull the upper part of the iris around the upper pole of the lens, for I have seen the spike perforate the iris and draw vitreous and this in the hands of a capable surgeon.

Drops of histamine with pilocarpine* are usually instilled into the anterior chamber at this point to get a good miosis if the pupil does not contract spontaneously. The non-toothed fine forceps that had been applied as a probe to steady the lens is used to depress the lens against the posterior capsule to allow the iris to contract well over the lens. The sutures are drawn to close the wound and are now completed by being passed through the conjunctival flap (Fig. 3, opposite).

* Histamine 2% with pilocarpine 5%, available in sterile 1-ml. ampoules from Saphar Laboratories Pty. Ltd., Johannesburg, S.A.

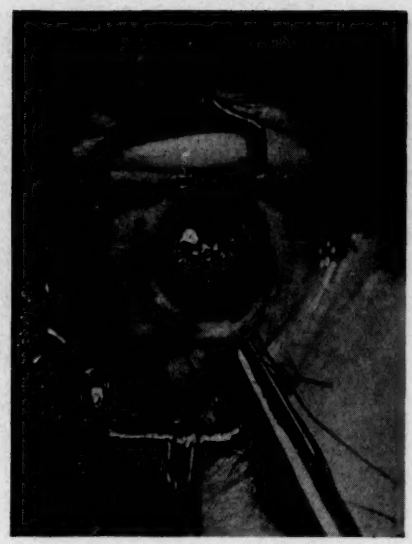

FIG. 3.—The two mattress-on-edge sutures have been drawn and are being completed by passing the needles through the conjunctiva. A largish bubble has been introduced into the anterior chamber.

A bubble of air is injected as soon as possible into the anterior chamber to separate endothelium from the acrylic implant in the pupil area. The centration of the acrylic is inspected, and if unsatisfactory a small blunt lens hook or iris repositor with a suitable double curve is introduced to press gently on the lens through the pupil. Pressure with a second repositor just outside the limbus is then applied to move the lens into the correct position. Any form of manipulation that presses the cornea and therefore the endothelium directly against the lens or indirectly through the iris must be avoided. The manipulation just described avoids this and also allows the lens to move relative to the iris. Pressure at the limbus alone, especially without any bubble of air in the anterior chamber, may move the lens, but the iris may move with it and be put on the stretch, subsequently tending to move the lens back to an eccentric position.

In some eyes it is easy to observe the position of the lens as its outline is discernible through the iris. In other cases, especially those with tough brown irides, it is difficult to see the position of the lens. To help with centration I have tried placing a small drop of blood on to the centre of the anterior face of the lens which is left to dry. It helps a great deal in some cases, but in those requiring manipulation the small blood clot is unfortunately soon wiped off.

When centration is satisfactory and the sutures have been tied, a few minims of hydrocortisone 25 mg./ml. are instilled into the anterior chamber, with enough air to get a good depth (Figs 4 and 5, overleaf). A further $\frac{1}{4}$–$\frac{1}{2}$ ml. is injected subconjunctivally below. Conjunctival sutures are finally inserted to fix the flap in position.

FIG. 4.—Hydrocortisone being injected into the anterior chamber, using a pipette made from a blood transfusion glass cannula, suitably cut and fitted with a rubber teat. The needle has been angled, the point cut off, and the end smoothed. It incidentally makes an excellent iris repositor.

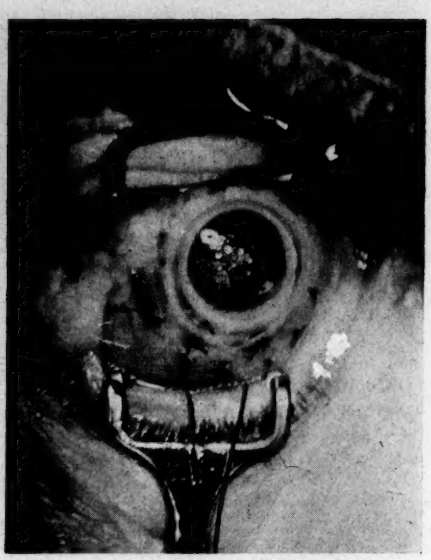

FIG. 5.—Completed operation, showing large bubble with several minims of hydrocortisone in the anterior chamber. On the average a little more is introduced than is shown in this illustration.

Post-operative Care.—This includes Seclomycin twice daily for 5 days. I aim at keeping the pupil about 3 mm. in diameter, and atropine is only used if the pupil is much smaller than this. After the histamine-pilocarpine drops, the pupil is usually very small and ung. atropine usually produces a 3-mm. dilation after the first application. Should this not occur the atropine is continued twice or three times a day until the desired pupil size is obtained. If at the second dressing (first post-operative day) it is noted that the atropine has made no difference to the pupil size, and especially if there is exudate occluding the pupil, a more powerful mydriatic such as 1 per cent. adrenaline is required. (It must be preceded by a drop of local anaesthetic.) Rarely the pupil enlarges more than the 3 mm. ideal and then a miotic is required.

Lens implant cases require more detailed care than straightforward cataract extractions, and twice-daily dressings are almost the rule for the first 4 to 5 days. My private cases as a group have better results than hospital cases where one had to rely on house surgeons to do the dressings. The hydrocortisone introduced into the anterior chamber lasts about 3 to 6 days depending upon the preparation. Topical ung. hydrocortisone is

started if thought advisable at this time, provided all striate keratitis has cleared. With my first eight acrylic implants no intra-cameral cortisone was used and some fairly severe iritic reactions occurred, producing very dense occlusive pupillary membranes that required several needling operations to establish a clear pupil. Having previously experimented with injections of cortisone suspensions into the vitreous and anterior chamber without producing ill effects, I tried the procedure of introducing a few minims of the suspension (25 mg./ml.) into the anterior chamber at the end of the operation. I found the results most pleasing, the iritic reaction being greatly reduced and the great majority of cases having a clear pupil. The usual acetate preparations of hydrocortisone take about 6 to 7 days to absorb completely. Occasionally, when a little more was introduced than usual, a denser clump formed on the iris which lasted longer. In two of these cases a small pucker developed in the iris where the hydrocortisone had remained clumped for 10 days.

The ordinary hydrocortisone acetate suspension contains various inert suspending agents such as carboxymethyl cellulose and 0·5 per cent. benzyl alcohol added as a preservative. Four of the failures to be described below developed a corneal dystrophy, and amongst other factors I suspected the benzyl alcohol. At my request Roussel Laboratories kindly made for me ampoules of hydrocortisone suspension without benzyl alcohol, using the free alcohol compound instead of hydrocortisone acetate. Some ampoules contained carboxymethyl cellulose as a suspending agent, and others contained the hydrocortisone compound in a very finely divided form in normal saline. It is the free alcohol form of hydrocortisone that reacts in the tissues and this preparation was therefore used to obtain the maximum antiphlogistic effect. This compound is absorbed from the anterior chamber in 2 to 4 days. The immediate result was better than with the hydrocortisone acetate preparation, but in a few cases a mild iritic reaction presented itself a few days after all the hydrocortisone had been absorbed. An ideal preparation would therefore probably be a mixture of the acetate and free-alcohol compounds in equal parts. No case treated with this preparation developed corneal dystrophy but the number is too small to be sure on this point.

Failures

As mentioned above this series included twelve failures. In four the lens is in excellent position and the pupil is clear, but the cornea has undergone a degeneration identical with a Fuchs's dystrophy. Commencing as a severe striate keratitis, the lesion progressed to full-thickness corneal haze and eventually to epithelial haze and small bullae. Two of these four cases were operated upon the same morning and it was subsequently discovered that a solution prepared by adding salt tablets to boiled tap water had been used for the anterior chamber irrigation instead of the usual "Vacoliter" normal saline. The possibility of endothelial damage by a probably hypertonic solution cannot therefore be excluded. In the

other two cases a fair amount of manipulation was necessary to centre the lens which persisted in sliding to one side or the other. A rather turgid vitreous bulged the posterior capsule forwards causing the lens to slide to the periphery. At that time centralization was achieved by applying pressure to the lens through the cornea, and this no doubt damaged the endothelium, while the hydrocortisone also probably delayed the healing of the damaged endothelium. It is for these reasons that I now get the eye as soft as possible pre-operatively and take every precaution to avoid damage to the endothelium. Additional topical cortisone therapy is not used until all striate keratitis has resolved. The anterior chamber irrigation must be kept to the minimum.

Two of these dystrophy cases have had corneal grafts. The one has achieved 6/12+ vision. In the other the graft has hazed but the eye is comfortable and future grafting is contemplated. Of the other two cases, one has refused further treatment, and the other is using hypertonic local applications. The corneal haze in the latter is not very marked and the oedema is settling.

In five cases the lens luxated into the anterior chamber. These were all cases of traumatic cataract, four being aphakic when first seen. As news of successful implants spread, relatives and friends of such patients came to see if they could have their unilateral aphakia corrected. Some of them were really not suitable—iris splits, broad posterior synechiae which were difficult to divide—and were warned that the lens might not stay in position and might have to be removed. In fact, the lenses had to be removed within 3 months from the four aphakic cases. Two unfortunately walked about for 2 to 3 weeks with the luxated lens resting against the endothelium. They too developed the Fuchs-like dystrophy mentioned above, though their corneae had healed uneventfully after the implant operation itself. The fifth luxation occurred 18 months after the original implant operation; in this case a traumatic cataract had been caused by an intra-ocular foreign body that had nicked the pupil margin at 12 o'clock. At the implant operation a rather broadish basal iridotomy—practically an iridodialysis—was done at 12 o'clock to allow the iris to sag a little to cover the upper pole of the lens, which was also centred well above the pupil centre. However, a puckering of the iris occurred round the upper pole of the acrylic implant, and despite the use of eserine drops the upper part of the iris was pulled up a little as a broadish posterior peripheral synechia formed between 10 and 2 o'clock. After 6 months the condition appeared static, with visual acuity 6/12 and all seemed satisfactory, but a year later the patient reported that a week previously he had felt a sudden pain, and that the vision, which had improved considerably during the year, had now deteriorated. The upper pole of the lens was found resting against the endothelium. The lens had apparently dropped a little more and the contracting posterior synechia above had broadened the gap caused by the small nick in the pupil edge, allowing the iris to slip over the upper pole of the lens. After removal of the lens the cornea, which had been hazy, settled satisfactorily. This is interesting when compared with the two cases that developed a corneal dystrophy, in which the endothelial contact had been present for 2 to 3 weeks.

Peripheral posterior synechiae causing the iris to pucker round the edge of the acrylic lens were noted in many cases. This is one reason for keeping the pupil contracted to about 3 mm.

In two other instances an implant was done after an intracapsular extraction.

Having heard that this was being done successfully, I first tried it on a patient who had developed acute glaucoma as a complication of a hypermature cataract. By the time of the operation there was no perception of light. The operation went off so well and the technical result was so pleasing that the same operation was done a month later in another patient in a seeing eye, and here too the result appeared to be excellent. However, a few weeks later the lens in the first case was seen to be sliding downwards between the iris and hyaloid membrane and it was soon obvious it would have to be removed. In the second case the same thing developed after several weeks and that lens too was therefore removed.

The last of this series of failures occurred in a case of heterochromic cyclitis. A moderately severe hyphaema occurred and left a rather dense occlusio pupillae. This was needled twice and a clear pupil was developing when glaucoma supervened. This did not respond medically and the patient refused further surgery. No other case of glaucoma as a complication was observed in this series.

Of these twelve failures, therefore, six or seven could have been avoided and improved technique should eliminate the rest. The intracapsular extraction cases are self-evident. Traumatic aphakia requires careful investigation and assessment: the iris sphincter must be active and intact and posterior synechiae must be easily divisible so that the acrylic lens can be evenly covered. The operation should only be attempted in cases of heterochromic cyclitis if haemorrhage seems unlikely and ocular tension is normal.

Minor Complications

Apart from the twelve failures described above, no other serious complication developed in this series.

Three cases developed a late haziness of the posterior capsule—after 2 years in one case, and after 1 year in two cases; posterior needling restored the vision fully in all three. Posterior needlings were done in 24 of this series; in 21, including fourteen of the traumatic cataract cases, about 3 months after the implant was done. This early posterior capsular haze is due to immaturity of the cataract and hyphaema.

The late hazing seen in three cases might have been due to the ingrowth of cells from tags of anterior capsule sandwiched between the lens and posterior capsule.

Needling of an anterior occlusio pupillae membrane was done in fifteen cases, six of which had had hyphaemas filling more than half the anterior chamber. Other large hyphaemas absorbed leaving no membrane, but some required several anterior or posterior needlings, and five had both anterior and posterior discissions.

The main point in the technique of posterior needling is focal spot illumination by means of a headlamp worn by the surgeon, which is adjusted before scrubbing up. A pre-operative miotic is advisable if the pupil is more than 3 mm. in diameter. Retrobulbar anaesthesia is used, and the needle is inserted into the vitreous body about 5 mm. posterior to the temporal limbus. The posterior capsule does not snap open when needled and a vertical as well as a horizontal cut is usually necessary to produce a small opening which is all that is necessary provided it is central. This requires careful pre-operative planning with the headlamp for illumination; a lamp held by an assistant is not satisfactory, the rays being too oblique.

Most of my cases developed a greater or lesser degree of compound myopic astigmatism with the implant. The power of the Ridley lens is 73D in air which is much greater than that of the normal lens.

In many of my cases the lenses have dropped towards the 6 o'clock meridian of the posterior chamber. This has occurred despite an initial high positioning of the lens. Possibly the hydrocortisone, by inhibiting the formation of adhesions, favours the gradual sag of the acrylic downwards where it comes to rest on the ciliary body. This has not caused any reaction, but it means that the centre of the pupil in an average 12 to 13-mm. cornea is about 2 mm. from the upper edge of the lens-diameter which measures 8·4 mm. This is my main reason for keeping the pupil at the most about 3 mm. in diameter. However, posterior peripheral synechiae have drawn the iris round the edge of the lens and in some cases the groove on the anterior surface of the acrylic is visible. Even in cases where the lens remains central, the relatively abrupt thick edge of the lens leaves a space between iris, posterior capsule, and lens edge. Retained lens matter, plus fibrin, can fill this space in parts, so favouring the formation of posterior synechiae, and puckering the iris. This in turn tends to displace the lens to one side or the other, distorting the pupil, and so favouring anterior dislocation.

Suggestions for an Improved Lens

For these reasons I consider a better form of lens to be of larger diameter (9·4 mm.) and thinner (1·5 instead of 2·4 mm.). This allows a thin taper edge instead of the relatively thick abrupt edge of the present lens. A wider area of separation of iris and posterior capsule is thereby achieved and should a peripheral posterior synechia form, any iris pucker around the thinner edge of the lens can be only very slight. Centration of the lens is easier, so that little manipulation is required, and the risk of astigmatism resulting from oblique and peripheral centration is less. The thinner lens means less forward bulging of the iris, which may cause occlusion of the angle and the development of glaucoma.

A new series of cases is now being tried with such a lens; its other measurements are anterior curvature 20 mm. and posterior curvature 12 mm. The results so far seem pleasing but the number of cases is not yet sufficient to allow definite conclusions to be drawn.

Summary

The results in 84 Ridley lens implant operations are discussed. Twelve failures are analysed with suggestions how to avoid them. Six of these twelve cases were of an experimental nature. Aspects of technique are described, including the value of Diamox pre-operatively, and hydrocortisone into the anterior chamber. A modified lens is suggested to give better refractive results, facilitate centration, and eliminate the bad effects of posterior peripheral synechiae.

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PRODROMAL MALIGNANT GLAUCOMA*

BY

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FAILURES in the surgical management of malignant glaucoma (von Graefe, 1869; Smith, 1891; Chandler, 1950; McDonald, 1954) call attention to the syndrome of prodromal malignant glaucoma in which success has been reported (Birge, 1956). Based on a new and possibly radical operation performed before the devastating complications which give rise to malignant glaucoma can occur (Birge, 1952, 1953, 1956; Hughes, 1955; Wenaas and Stertzbach, 1955), this new concept of an old problem offers some hope to the otherwise hopeless individual afflicted with malignant glaucoma.

Von Graefe (1869) described malignant glaucoma as "a new and acute glaucomatous process brought about by surgery, which is unusual only in the continued failure of the anterior chamber to form". The increasing intra-ocular tension which followed this series of events was usually treated by surgical procedures on the lens, sometimes with less than desired success (Pagenstecher, 1877; Rheindorf, 1887; Smith, 1891; Zeeman, 1935).

Prodromal cases can be defined pre-operatively as those in which the likelihood of lenticular complication is greater. The majority can be specifically diagnosed before surgery.

Signs and Symptoms of Prodromal Malignant Glaucoma

Each case of chronic non-congestive glaucoma in which any of the following additional findings occur is in danger of developing malignant glaucoma after surgery.

Prodromal malignant glaucoma occurs when the eye is too small as in microcornea (Smith, 1891), or when the lens is too large as in acquired myopia after surgery or cataract formation (Chandler, 1950), extreme hyperopia, extreme age, and usually, although not always, in narrow angle glaucoma (Vail, 1956).

When the syndrome of prodromal malignant glaucoma is diagnosed, the importance of any lens factors is recognized, and with proper treatment the "new and acute glaucomatous process" specified by von Graefe can be avoided.

The importance of recognizing an over-large lens before surgery is undertaken cannot be underestimated if malignant glaucoma is to be prevented. The diagnosis must be arrived at in the prodromal stage if preventive measures are to be successful.

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The prodromal stage of malignant glaucoma usually exists for many months before the lens is displaced forward by the surgical procedures designed to alleviate the chronic glaucoma. Ample time for study and reflection before glaucoma surgery is available to the surgeon in most cases. Despite the difficulty of measuring the size of the lens, there are several methods which serve adequately, if only the surgeon will consider the behaviour of the lens as well as the problem of glaucoma.

In the usual course of events, malignant glaucoma occurs in both eyes, frequently at different times. After the loss of the first eye from malignant glaucoma, the prodromal stage should easily be recognized in the second eye.

The recognition of the prodromal stage of malignant glaucoma in the first eye offers gratifying possibilities, in that the loss of the first eye may be avoided, and treatment of the second eye is often thereby facilitated (De Voe, 1950).

Management of Prodromal Malignant Glaucoma

Simultaneous consideration of the two aetiological processes which join to produce malignant glaucoma can most profitably be accomplished in the prodromal stage.

While glaucoma can be controlled it can be managed medically, but as soon as surgical measures are indicated, the importance of the lens becomes paramount.

Removal of the lens before it becomes jammed into the narrow anterior chamber through forward displacement is the method most likely to be successful, both theoretically and practically, for the prevention of malignant glaucoma.

At the time of lens removal, glaucoma surgery, such as sclerectomy or iridencleisis, can easily be added to the lens extraction (Birge, 1952, 1956; Hughes, 1955; Wenaas and Stertzbach, 1955). Glaucoma surgery can be done at a later time, when multiple operations are not contraindicated, although it is more advantageous to do all the surgery at one time. Surgical treatment aims at producing simultaneous relief of both the factors which lead to malignant glaucoma, namely chronic non-congestive glaucoma and the dangerously enlarged lens.

The presence of cataractous changes is of prime importance only in cases that do not belong to the category of prodromal malignant glaucoma.

In prodromal malignant glaucoma the clarity of the lens is a minor consideration. The increased size of the lens in relation to the eye or the anterior chamber determines the indication for lens removal.

A large clear lens can produce malignant glaucoma and therefore must be removed in the prodromal stage. Fortunately, most clear lenses, in my experience, have, upon removal, given clinical evidence of cataractous changes, even though these were not visible ophthalmoscopically through the miotic pupil.

Case Reports

The first case illustrates the cure of prodromal malignant glaucoma and the benign effect on the second eye of a double operation on the first eye.

Case 1, a 70-year-old man, came to us in 1946 with complaints concerning his right eye. Refraction showed that he had developed acquired myopia of −1 D in the right eye and that the left eye remained +1·5 D hyperopic. A slight elevation of ocular tension (35 mm. Hg) was controlled by 1 per cent. pilocarpine twice a day for 8 months, and then the dosage had to be increased to four times a day. Faint lens changes were noted in 1947, but visual acuity was 20/20 in each eye with glasses.

The ocular tension in the right eye gradually required increasing doses of pilocarpine to 4 per cent. four times and then six times a day. The anterior chambers were quite narrow. The tension in the left eye never required more than 2 per cent. pilocarpine three times a day to stay controlled.

Operation on the right eye was performed for the swollen lens and narrow angle glaucoma on March 18, 1952, an extracapsular extraction being obtained and an iridencleisis being performed at the same time. No miotic has since been required in the right eye, and the visual acuity is now 20/20 with correction. The bleb is atrophic.

The left eye is still under control with 2 per cent. pilocarpine five times a day (ocular tension 23 mm. Hg and visual acuity 20/25). No acquired myopia has yet occurred in the left eye, but the anterior chamber is less than 1 mm. deep.

The second case illustrates the restoration of vision and normal ocular tension in the second eye with prodromal malignant glaucoma, after the loss of the first eye with malignant glaucoma.

Case 2, an 82-year-old female, had had narrow angle glaucoma for 12 years. Her right eye had been operated on for acute glaucoma, an iridectomy having been performed in 1948. A mature cataract was present in the right eye in 1954. This eye was controlled by 2 per cent. pilocarpine three times a day with 0·25 per cent. eserine at night. There was poor light projection.

The visual acuity in the left eye was counting fingers only. Every morning she looked for the light in her bedroom to see whether it was there and whether she could still see. She was under care for blindness, using talking books and having people read to her.

The ocular tension in the left eye remained controlled with pilocarpine and eserine until an automobile accident in December, 1954. Thereafter, even with pilocarpine 4 per cent. five times a day, the ocular tension in the left eye rose to 48 mm. Hg, while that in the right eye was 40 mm. Hg.

In spite of her age an operation was performed, and the cataract removed from the left eye, with iridencleisis, so that 18 months later the visual acuity was 20/30, though the visual field was only 10°. Our diagnosis was chronic narrow angle glaucoma with mature cataract or malignant glaucoma.

She required no further miotic therapy and maintains a good bleb.

The third case illustrates the effect of multiple operations in bilateral chronic narrow angle glaucoma with a clear lens, microphthalmos, and prodromal malignant glaucoma.

Case 3, a 65-year-old female, with chronic narrow angle glaucoma in eyes with a corneal diameter of 10 mm. and hyperopia of plus 3·00, plus ·50 × 90, O. U., had visual acuity of 20/20 in each eye. She had had glaucoma since 1951 and was using 2 per cent. pilocarpine five times a day in each eye to keep the tension moderately controlled (right

23 mm. Hg and left 27 mm. Hg). The lenses were clear. She had psychiatric consultation for her anxiety, but no additional help was available since her fear of blindness was based on organic disease.

When her tension rose to 50 mm. Hg in the left eye and remained elevated from March 23 to April 18, 1955, an iridencleisis with sclerectomy was performed on the left eye. This resulted in a 1-cm. bleb and controlled the tension in the left eye in spite of synechiae and iritis, but a cataract developed. This was removed in June, 1956, and was followed by discission. Visual acuity in the left eye in December, 1956, is 20/70, and in the right 20/20. The right eye is still under therapy with 8 per cent. pilocarpine every 2 hours.

The removal of a clear lens in the first eye would have been advisable and would have saved her from multiple operations. That procedure will be followed in the near future on the second eye.

The fourth case illustrates malignant glaucoma over a 13-year period.

Case 4, a 60-year-old female, was first seen by us in March, 1953, when her left eye had been blind since glaucoma surgery elsewhere in 1943. She reported that she had seen ten doctors at that time and that the vision was severely impaired before diagnosis and surgery were undertaken. The left eye now shows a mature cataract, old iridectomy, and synechiae. She shows a mild chronic anxiety state.

Visual acuity in the right eye is 20/25 with +3·5 D sph. The corneal diameter is 9 mm. The visual right field is still good but shows a nasal loss. There is a large glaucomatous excavation in the nervehead and the patient sees haloes and has frontal headache at intervals.

She was still receiving medical treatment in November, 1956 (Table), but surgery is expected in the near future.

TABLE

Date	Visual Acuity		Ocular Tension (mm. Hg)		Treatment	
	Right	Left	Right	Left	Right	Left
Mar. 18–53	20/25	Blind	29	22	pilo 1% twice daily	None
Apr. 8–53	20/25 with glasses	Blind	25	22	pilo 1% twice daily	None
May 7–53	20/25 with glasses	Blind	29	20	pilo 1% three times a day	None
June 5–53	20/25 with glasses	Blind	26	20	pilo 2% 6-hrly	None
June 19–53	20/25 with glasses	Blind	30	22	pilo 2% 3-hrly	None
Sept. 9–53	20/25 with glasses	Blind	25	20	pilo 2% 3-hrly	None
Dec. 14–53	20/25 with glasses	Blind	25–27	20	pilo 2% 3-hrly	None
Feb. 24–54	20/25	Blind	27–29	20	pilo 2% six times a day	None
May 18–54	20/25 with glasses	Blind	22	20	pilo 2% six times a day	None
Dec. 24–54	20/25 with glasses	Blind	27–30	20	pilo 2% six times a day	None
Sept. 7–54	20/30 with glasses	Blind	25–27	15	pilo 2% six times a day	None
Jan. 26–55	20/25 with glasses	Blind	20–23	17	pilo 2% six times a day	None
Apr. 27–55	20/25 with glasses	Blind	23	Soft	pilo 2% six times a day	None
Aug. 3–55	20/25 with glasses	Blind	24–27	17	pilo 3% six times a day	None
Dec. 15–55	20/25 with glasses	Blind	37–40	20	pilo 4% 2-hrly	Pheno-barbitone
Feb. 23–56	20/25 with glasses	Blind	27	23	pilo 4% 2-hrly	Pheno-barbitone
Apr. 25–56	20/25	Blind	22	Soft	pilo 4% 2-hrly	Pheno-barbitone
Aug. 15–56	20/25	Blind	27	Soft	1 D acquired myopia	
Nov. 21–56	20/20	Blind	27	Soft	Same—nervous over holidays	

This is certainly prodromal malignant glaucoma in the second eye. The tension variations are glaucomatous. Lens factors are beginning to occur; there is acquired myopia but no cataract.

In a microphthalmic one-eyed 60-year-old with prodromal malignant glaucoma the operation of choice is lens extraction with a filtering operation

The fifth case illustrates prodomal malignant glaucoma in a large eye, from 1949 to 1956, complicated by hypertension, cardiac failure, and allergy to all glaucoma medication. Eventually an operation restored vision and normal tension.

Case 5, a nervous woman aged 75, when first seen on September 7, 1949, had the left eye blind from undiagnosed glaucoma. The ocular tension in the right eye was 25 mm. Hg and in the left 65 mm. Hg. The patient refused surgery because of fear and the necessity to care for her ailing husband.

She was treated with 1 per cent. pilocarpine twice daily in the right eye (visual acuity 20/25) and 4 per cent. pilocarpine with Furmethide 10 per cent. at frequent intervals in the left eye until she developed a local dermatitis in August, 1950. A change of medication to prostigmine benefited her until April, 1952, when she was put on eserine. This worked until February, 1953, when she went back to pilocarpine in the right eye 2 per cent. 3 times daily and in the left eye 6 per cent. every 3 hrs. In June, 1953, the pilocarpine in the right eye had to be increased to 4 per cent. every 3 hrs. and she had nearly constant chronic lid allergy, in spite of anti-histaminic drugs and changes in medication.

The visual acuity in the right eye gradually failed to 20/50 by mid-1955. She refused operation, even though the tension occasionally registered 34 to 40 mm. Hg. There were a few hypertensive retinal haemorrhages seen from time to time, and she survived one spell of cardiac decompensation in 1954.

By March, 1956, the right eye had almost no anterior chamber, and an immature cataract, and was frequently red from the allergic conjunctivitis; Diamox kept the ocular tension fairly well controlled until operation on October 23, 1956.

She now has a restoration of vision to 20/30 or 20/40 without medication, and for the first time in years has clear skin and a white eye. The bleb is small and draining well. The left eye will, of course, have to be removed when it becomes painful.

The sixth case illustrates an explosive type of prodromal malignant glaucoma in a man with microcornea; surgery brought about restoration of vision and ocular tension and ability to return to work 5 weeks later.

Case 6, a 61-year-old man, noted that his glasses were not comfortable on March 2, 1956. At this time the ocular tension was 65 mm. Hg. in the right eye and 48 mm. Hg in the left. The visual acuity was 20/40 in the right eye and 20/20 in the left. He was placed on 2 per cent. pilocarpine without much improvement.

4 per cent. pilocarpine kept the tension under control until September, 1956; 6 per cent. pilocarpine was prescribed on September 24, 1956, but the ocular tension in the right eye was never reduced below 30 mm. Hg. The ocular tension in the left eye was 25 mm. Hg. on 8 per cent. pilocarpine six times a day with two Diamox tablets in addition.

After consultation, the patient returned for surgery which was performed on October 9, 1956. The lens was removed from the right eye and a sclerectomy with iridencleisis was performed.

Five weeks after operation the vision was restored with an aphakic glass to 20/30 without any medication.

The left eye is being maintained on 8 per cent. pilocarpine every three hours without Diamox.

There was no opacity of the lens in this case, but the lens was quite yellowish in colour, the anterior chamber was less than 1 mm., and the corneal diameter was 8·5 mm.

Sometime in the near future an operation will have to be performed on the left eye.

Summary

The operation of choice in prodromal malignant glaucoma is lens extraction combined with a filtration procedure, performed at one operation to avoid multiple surgery.

The operation is indicated when the intra-ocular pressure begins to be uncontrollable, as for instance, when pilocarpine of more than 4 per cent. solution is required at 2-hour intervals or less.

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CORRESPONDENCE

OXYPHENONIUM AS AN ATROPINE SUBSTITUTE

To the Editorial Committee of the BRITISH JOURNAL OF OPHTHALMOLOGY

SIRS—In my recent article on the use of oxyphenonium as an atropine substitute (Roper-Hall, 1957) I stated that a previous atropine substitute, Lachesine, had been withdrawn from production. This was true at the date when the article was written in November, 1956, but I have recently learned that Lachesine is now being manufactured again.

Yours faithfully,
M. J. ROPER-HALL.

139 MOOR GREEN LANE,
MOSELEY, BIRMINGHAM, 13.
March 14, 1957.

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BOOK REVIEW

The Visual Fields. A Text-book and Atlas of Clinical Perimetry. By DAVID O. HARRINGTON. 1956. Pp. 327, 234 illus., 9 col. pl., bibl. Kimpton, London. (£6).

The value of perimetry in ophthalmology and particularly in neuro-ophthalmology has been fully established, but as long as it is considered a dull and boring procedure for examiner and patient alike, full use will not be made of the method. The reader of this book will surely find his interest stimulated and will feel challenged by the problems presented to a livelier appreciation and application of perimetry.

In spite of the fact that the author has been instrumental in developing several new and valuable methods, he emphasises again and again that the apparatus is of minor importance, and that "the man behind the perimeter is more important than the equipment he uses".

The first section of the book is concerned with technique and gives much useful advice on using such simple methods as confrontation. The standard perimeters and tangent screens are described and special techniques, such as angioscotometry, ultra-violet light with fluorescent test objects, and flicker fusion fields, are described in detail. A multiple-pattern method, using fluorescent targets for rapid routine field testing, is particularly interesting, and would be very suitable for screening large numbers of patients. The test can be done by a nurse or technician with the minimum of training and, while in no sense replacing ordinary methods, might well become a part of every routine ophthalmological examination.

The anatomy of the visual pathways is described very lucidly with the aid of excellent anatomical drawings and diagrams. The normal visual field is compared to an island hill of vision surrounded by a sea of blindness, after the manner of Traquair, whose influence throughout the book is acknowledged by his one-time pupil.

The physiological and psychological influences on the size of the fields are carefully pointed out and the necessity of adapting one's methods to the individual patient is emphasized.

The descriptions of abnormal fields are clearly illustrated schematically and by reference to actual cases. The style throughout is concise but highly readable. The standard of production is high, and this combined with the many illustrations probably accounts for the rather high price of £6. It is unfortunate that a text-book so suitable as a reference volume for trainee ophthalmologists and neurologists should be so expensive. Apart from its excellence as a training manual every ophthalmologist and neurologist will find something of interest and value herein.

NOTES

FACULTY OF OPHTHALMOLOGISTS

Study Tour to France, 1956

Paris.—Under the leadership of Mr. Graham Wright, a party visited the Quinze Vingts de Paris, founded by Louis IX in 1260 for the care of 300 ("fifteen score") indigent blind persons. We saw the out-patient clinics and surgical work of Drs. Guillaumat, Schiff-Wertheimer, and Kalt; Dr. Kragevitch demonstrated the pleoptic treatment of squint; Dr. Dubois-Poulsen showed us the research laboratory, a cramped, dark, and unventilated cellar in which a great deal of original work is being done on the visual fields.

Nantes.—On the fourth day we journeyed to Nantes, stopping on the way to visit Chartres Cathedral. At Nantes, in contrast to the old, but very charming, Quinze Vingts, we saw the modern functional clinics and theatres of Professor Sourdille and Dr. Legrand. We watched thirteen operations, including four corneal grafts, and saw the great emphasis which is placed on efficient anaesthesia. Dr. Tessier, plastic surgeon to the Hôpital Foch, Paris, then showed the use of a fascial sling for ectropion following facial palsy and Blair's operation for epicanthus. Five members of our party read papers. The following day being Sunday, Professor Sourdille took us all to La Baule.

Paris.—On our return to Paris, we visited the Hôpital Curie, where Dr. Dollfus demonstrated radiotherapy. The party then divided into four groups and took turns to visit the ophthalmic departments of seven Paris hospitals. Operations and the work in the wards and clinics were demonstrated in each, and each hospital had something different to interest and instruct us. Professor Offret demonstrated paracenteses of the anterior chamber and examination of the aqueous fluid. Dr. Morax explained his special record cards for easy statistical surveys.

At a special meeting of the *Société française d'ophtalmologie*, held on the last day, one of our party, Dr. O. Walker, was asked to preside, and several interesting papers were given.

This was a most instructive and well-planned tour and we greatly appreciated our French colleagues' work in organizing it, and their wonderfully generous hospitality both formal and private.

Our joy is saddened by the news of the death of Professor Sourdille who was so active and full of life, and we express our deepest sympathy to his family and colleagues.